



Florida Scientist

AUG - 1986

Volume 43

Fall, 1980

No. 4

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FLORIDA SCIENTIST

QUARTERLY JOURNAL OF THE FLORIDA ACADEMY OF SCIENCES
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Published by the Florida Academy of Sciences, Inc.
810 East Rollins Street
Orlando, Florida 32803

Printed by the Storter Printing Company
Gainesville, Florida 32602

Florida Scientist

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WALTER K. TAYLOR, *Editor*

HENRY O. WHITTIER, *Editor*

Volume 43

Fall, 1980

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Physical Sciences

X-RAY POWDER DIFFRACTION DATA FOR THE PHOSPHATE MINERALS: VAUXITE, METAVAUXITE, VIVIANITE, Mn-HETEROSITE, SCORZALITE, AND LAZULITE

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ABSTRACT: *X-ray powder diffraction patterns and related data are presented for 6 phosphate minerals. The existing X-ray data for these minerals are inferior and the information presented here should serve as a much improved standard for identification.*

PUBLISHED powder diffraction data for a substantial number of phosphate minerals are far from satisfactory. In some instances it is difficult or impossible to use an X-ray powder diffraction pattern to identify a certain pure phosphate mineral even though data for the mineral have been published and are included in *Selected Powder Diffraction Data for Minerals* (1974). This unfortunate situation exists because the reference data for a certain mineral may include lines which do not belong to the mineral or because certain strong lines may not be listed. In other instances it is possible to identify a phase without serious difficulties, but it is impossible to account for all the observed lines because the reference data are incomplete. This is especially troublesome where the material being studied is a mixture and identification of all phases in the mixture is required. A particular line in the pattern may be an unlisted line for an identified phosphate phase, or the line may belong to an entirely different phase.

New X-ray data should be published, when available, to replace data which are inaccurate, incomplete, or are not indexed or not correctly indexed. Recently the senior author has published X-ray powder diffraction patterns for the phosphate minerals crandallite (1972, 1978), wavellite (1974), paravauxite (1977), heterosite (1978), and lithiophilite (in press). The data for these minerals and for the minerals included in this report (vauxite, metavauxite, vivianite, Mn-heterosite, scorzalite, and lazulite) represent substantial improvements over existing diffraction data in the literature.

SAMPLES—The specimens were obtained from the mineral collection of the Department of Geology, University of Florida, from various commercial suppliers of mineral specimens, and in one instance, from the National Museum of Natural History.

Preliminary X-ray powder diffraction patterns, rough quantitative chemical analyses (by X-ray fluorescence), and optical examinations led to the final selection of the best available samples to use for the collection of powder diffraction data. In most cases, each specimen used represents a well-known occurrence of that species. Among the species included in the study satisfactory specimens were found for all species except purpurite. Among the 6 samples of labeled purpurite, 5 were nearer to the heterosite end of the purpurite-heterosite series and 1 was ferrisicklerite. The particular Mn-heterosite which was finally used was chosen because it is the type purpurite originally described by Graton and Schaller (1907).

PREPARATION OF SAMPLES—Preparation of samples involved crushing, hand picking for purity and sieving. In addition, samples of lazulite and scorzalite were separated from associate minerals by specific gravity using tetrabromethane and by use of a magnetic separator. One fraction of each clean sample was reserved for chemical analysis, while the other portion was ground to pass a 325 mesh sieve and was used for X-ray diffraction.

For X-ray diffraction at least 3 preparations were used for each sample. One fraction was prepared with collodion and amyl acetate as a smear on a glass slide or was sprinkled onto a glass slide coated with a thin layer of vaseline. A second fraction was mixed with about 20% silicon (National Bureau of Standards SRM-640) prior to being smeared with collodion and amyl acetate on a glass slide. A third fraction was mixed with 50% synthetic corundum (Al_2O_3 , 0.3 micron, Linde A) prior to sprinkling on a glass slide coated with a thin layer of vaseline. The slide with silicon was used to obtain the d -spacings and these were corrected by using silicon as an internal standard. The value of I/I_c was obtained from the slide mixed with synthetic corundum and the values of $I_{relative}$ were obtained either from the first or second preparation.

X-RAY ANALYSIS—Scans were made with a General Electric XRD-5 diffractometer at $0.2^\circ 2\theta/\text{min}$ from an appropriate low angle to $90^\circ 2\theta$ using $Cu K\alpha$ radiation obtained from a copper target tube and a diffracted beam graphite monochromator. Scans were made with a 3° divergence slit, MR Soller slit, a take-off angle from 2° to 4° , and a detector slit from 0.02° to 0.1° .

The 2θ angle for each diffraction line was usually obtained by estimating the center of gravity of the approximate top 20% of the line profile. Silicon was used as an internal standard to correct for systematic errors in the 2θ angle of each reflection. A graphical representation of 2θ error ($\Delta 2\theta$) was constructed by comparing the observed 2θ angle of each silicon line with the ideal 2θ angle corresponding with that line. This error function of $\Delta 2\theta$ against 2θ (assumed to be linear between adjacent silicon lines) was used to

correct the 2θ angle for each reflection from the mineral. The slope of the error graph was extrapolated to low 2θ angles as needed.

At low and moderate 2θ angles the corrected 2θ angles were converted to d -spacings using the weighted average wavelength (1.54178) for the α_1, α_2 doublet for Cu K-radiation. At higher 2θ angles, where the silicon lines were clearly resolved into α_1 and α_2 components and where the lines for the mineral were sharp, the 2θ angles were converted into d -spacings using the α_1 wavelength (1.54051).

Corrected d -spacings were used with the computer program of Appleman and Evans (1967) to obtain a least squares refinement of lattice parameters. A weighting factor of $1/d^2$ was used for each d -spacing to minimize the larger errors inherently present at lower 2θ angles.

$I/I_c - I/I_c$ is the integrated intensity ratio for the strongest line of a specified mineral to the strongest line of corundum. The observed value of I/I_c was obtained for each species, where there was no interference with corundum, by repeated scans across the 113 line for corundum and across the strongest line for the mineral in question. The average peak height ratio from the several scans was recorded. Where there was mild interference a correction was made for the contribution of the interfering line and where interference was severe the measurement was not attempted.

CALCULATED DIFFRACTION DATA—In addition to the observed patterns, a computer-simulated diffractometer chart and calculated d -spacings and relative intensities were obtained for each mineral. These were obtained using the FORTRAN IV program for calculating X-ray powder diffraction patterns -- version 5 (Clark, Smith and Johnson, 1973), with crystal structure data from various sources. The calculated patterns were extremely useful in distinguishing lines due to impurities, in indexing the observed reflections, for evaluating the quality of previously published powder diffraction patterns, and in evaluating the reliability of the structure determination. Refined lattice parameters for each of the minerals included in this study were in good agreement with those reported with the crystal structure data which was used to calculate the X-ray powder diffraction patterns. Because of this close agreement, the calculated patterns served to disclose errors in indexing of previously published powder diffraction data.

Hubbard, Evans and Smith (1976) recommend reporting a standard scale factor (γ) with calculated powder diffraction patterns. This practice permits conversion from relative intensity to absolute/relative intensity. They also point out that the scale factor, γ , may be used with appropriate data for corundum to calculate "the reference intensity ratio," I/I_c .

The calculated value of I/I_c was obtained for each mineral from the calculated value of γ (the scale factor) for the mineral and values of γ , linear absorption coefficient, and density for corundum given by Hubbard et al. (1976).

CHEMICAL ANALYSIS—Preliminary qualitative and some approximate quantitative analyses were done by X-ray fluorescence. Quantitative

analyses for phosphorus were done by colorimetric methods and/or by atomic absorption spectrophotometry. Other elemental analyses were done by atomic absorption spectrophotometry.

RESULTS—The results are in Tables 1 and 2. Most of the color descriptions are based on the nomenclature and system of abbreviations of the G.S.A. Rock Color Chart. Density calculations are based upon unit cell volume determined from lattice parameters refined from the powder diffraction data and upon the approximate chemical formula. The approximate chemical formula was determined as the mixture of end member formulas that corresponded most closely to the chemical analysis.

Vauxite: $(\text{Fe}^{+2}\text{Al}_2(\text{PO}_4)_2(\text{OH})_2 \cdot 6\text{H}_2\text{O})$. The specimen of vauxite was a pale blue (5 B 7/6) aggregate of crystals from Llallagua, Bolivia. Chemical

TABLE 1. Powder diffraction data for scorzalite, lazulite, and metavauxite. I is relative intensity and dA is d -spacing in angstrom units.

Scorzalite			Lazulite			Metavauxite		
dA	I	hkl	dA	I	hkl	dA	I	hkl
6.13	21	100	6.18	5	100	10.12	69	100
4.72	22	011	4.73	18	111,011+	6.967	5	110
3.62	6	102	3.63	4	020,102	5.608	5	011
3.24	89	112	3.23	100	112	5.095	50	200,111
3.20	100	111,211	3.20	59	111,211	4.793	20	020
3.15	55	021,202+	3.14	55	021,202+	4.687	100	111
3.090	40	200	3.077	42	200	4.486	15	210
2.568	10	122	2.866	1	212	4.337	79	120
2.554	28	211	2.548	18	221,122	3.985	54	211
2.376	2	022,222	2.347	4	220,302	3.942	5	021
2.348	6	302,102	2.255	10	130,031+	3.771	7	121
2.264	11	031,213+	2.235	2	312	3.564	21	211,121
2.235	5	312	2.221	5	311,211	3.486	15	220
2.223	20	311,211	2.053	2	300	3.456	14	002
2.052	7	300	2.007 b	8	132,131+	3.395	18	102,300
2.021	6	132	1.983	14	223	3.216	17	112,221+
2.009	12	131,313+	1.977	13	310	3.131	5	102
1.989	12	223	1.963	6	221,122	3.050	12	202,130+
1.975	15	310,322+	1.818	5	040	2.979	18	112
1.965	7	221	1.805	9	204,023	2.904	11	031,212
1.826	7	040	1.787	3	402	2.799	24	022
1.811	5	204	1.755	<1	214	2.764	76	320,122
1.808	7	023	1.745	1	141	2.749	32	131
1.787	8	402,320	1.736	2	412,304+	2.708	3	230
1.752	4	140,141	1.692	2	133,233+	2.672	26	321
1.738	4	304,412+	1.686	3	114,132+	2.627	3	122
1.701	2	223,133	1.672	2	113	2.583	20	231
1.690	3	114,132+	1.664	3	311,411	2.539	2	400
1.686	3	331,231	1.620	11	224	2.511	3	312
1.677	3	113,413	1.602	8	222	2.473	11	321
1.666	2	411,311	1.580	5	333	2.458	5	231,410
1.624	11	224	1.571	18	042,242	2.416	9	411
1.604	8	222	1.568	16	330	2.344	7	032,222
1.584	7	333,033	1.564	9	404,240	2.325	7	330,140
1.577	17	042,242	1.561	7	423,004	2.285	10	322
1.571	16	330,240+	1.548	3	421	2.266	32	331,041+
1.564	9	404,423+	1.540	8	400	2.246	4	113,420
1.549	3	421	1.437	2	342,432+	2.214	10	421,411+
1.540	14	400	1.433	1	142,341	2.165	3	240
1.507	<1	410	1.415 b	1	151,302+	2.153	1	213

1.443 b	2	342,142+	1.410 b	5	134,315+	2.141	14	331,412
1.423	3	151,150+	1.399 b	1	133,431+	2.125	13	113
1.414	6	315,134+	1.389	3	312,512+	2.074	13	023,123
1.410	5	133,433	1.361	<1	340	2.059	14	232,421+
1.399 b	1	431,513	1.350	2	152	2.008	3	223
1.391	3	312,512	1.335	2	225,514	1.993	3	313,422+
1.364	2	340	1.323	2	223,522+	1.983	7	511,123
1.356	2	152,251+	1.281	2	425	1.964	14	142,042+
1.338	3	225,514	1.275	7	442	1.92	1	341
1.334	3	114	1.272	5	242	1.885	3	242,150
1.324	3	223,522+	1.261	2	421	1.868	23	520,521+
1.287	1	244	1.239 b	1	253,153+	1.849	3	431
1.281	3	425	1.192	1	353,316+	1.818	3	233
1.278	11	442,242	1.188	2	061,161+	1.799	4	133,413+
1.261	1	421,344+	1.184	5	534,350+	1.785	1	250,242+
1.245	<1	253,153	1.181	2	134,044	1.759	6	342,251+
1.239	2	335,251	1.176	1	025,604+	1.741	20	440,104
1.196	<1	353,061+	1.173	1	431,440	1.713	11	251,531+
1.191	<1	316,350+	1.170	<1	204,416	1.692	6	600
1.188	3	534	1.166	1	602,520+	1.653	5	502,043+
1.185	3	134,206+	1.128	<1	062,452+	1.646	5	432,342+
1.182	2	025	1.125	1	226	1.623	4	304
1.177	2	531,431+	1.121	<1	543,106	1.619	4	024,252
1.174	2	604,313	1.115	2	224,154	1.609	4	442,602+
1.172	<1	204	1.109	1	153	1.596	2	351,620+
1.167	2	520,602	1.094	<1	511	1.576	6	413,160
1.153	<1	261,162+				1.561	3	252,522
1.134	<1	623,062+				1.549	4	523
1.127	2	226				1.543	4	352
1.119	2	342,154+				1.500	2	
1.116	2	224				1.487	3	
1.115	2	153				1.474	1	
1.111	1	035,351+				1.467	2	
1.094	1	511,611				1.463	4	

analysis for the major elements recalculated as oxides yielded 32.3% P_2O_5 , 22.0% Al_2O_3 , and 14.2% FeO .

Ninety-eight lines were observed to $d = 1.095$, whereas Sabina and Traill (1960) (JCPDS file card #14-210) show only 34 lines to $d = 1.434$. The omissions and indexing errors on card #14-210 are too numerous to cite individually. Unequivocal indexing of the reflections was considered feasible only to $d = 1.800$. The unit cell parameters are $a = 9.142(3)$ Å, $B = 11.599(3)$ Å, $c = 6.158(2)$ Å, $\alpha = 98.29(2)^\circ$, $\beta = 91.93(3)^\circ$, and $\gamma = 108.27(3)^\circ$. These are in very close agreement with the values $a = 9.13$ Å, $b = 11.59$ Å, $c = 6.14$ Å, $\alpha = 98.3^\circ$, $\beta = 92.0^\circ$, and $\gamma = 108.4^\circ$, reported by Baur and Rao (1968) for a crystal also from Llallagua, Bolivia. The calculated value of I/I_c is 1.28 and the calculated density is 2.401. Overlapping of lines from corundum and vauxite precluded the accurate measurements of I/I_c .

Metavauxite: $(Fe^{+2}Al_2(PO_4)_2(OH)_2 \cdot 8H_2O)$. The sample of metavauxite is from Llallagua, Bolivia, and represents a well-known occurrence of this species. The mineral is white and occurs as aggregates of radiating acicular crystals up to several centimeters in length. Analysis for major elements recalculated as oxides yielded 30.0% P_2O_5 , 20.6% Al_2O_3 , and 15.1% FeO .

Because of the complexity of the pattern it was not feasible to attempt indexing past $d = 1.54$. Even for reflections of larger d -spacings there are

TABLE 2. Powder diffraction data for Mn-heterosite, vivianite, and vauxite. I is relative intensity and dA is d -spacing in angstrom units.

Mn-Heterosite			Vivianite			Vauxite		
dA	I	hkl	dA	I	hkl	dA	I	hkl
4.874	65	020	7.880	30	110	10.85	100	010
4.288	88	011	6.714	100	020	8.641	9	100
3.739	24	120	4.890	43	200	8.149	9	110
3.70	3	101	4.532	19	001	6.069	10	001
3.454	92	111	4.340	8	111	5.908	12	110
3.421	29	021	4.071	14	130	5.712	3	011
2.941	47	121	3.972	<1	220	5.457	20	120
2.914	99	200	3.846	33	201	5.185	<1	101
2.688	12	031	3.630	8	111	4.971	7	111,011
2.499	4	220	3.352	3	221	4.780	1	101,111
2.440	100	131	3.202	38	131	4.582	7	111,210
2.410	43	211	2.972	51	201,311	4.417	5	021
2.322	20	012	2.889	2	131	4.324	8	200,121
2.250	12	140	2.768	8	240	4.053	2	120
2.217	13	221	2.701	31	221,041	3.955	<1	111
2.173	14	041	2.637	14	330	3.850	<1	121
2.155	12	112,022	2.591	5	150	3.754	<1	021
2.036	4	141	2.527	19	241,331	3.667	4	211,201
2.015	6	122	2.428	18	401	3.632	8	210,211+
1.976	10	231	2.317	14	151,112	3.440	1	221,131
1.924	2	032	2.288	5	421,202+	3.361	9	031,201+
1.873	2	240	2.228	12	241	3.315	3	211,221
1.848	10	202	2.188	11	151,022+	3.045	10	131,012+
1.828	5	132	2.104	3	312,331	2.956	12	220,211+
1.816	16	212	2.075	12	350,112	2.907	9	031,131
1.801	5	301	2.036	1	260	2.881	12	300,112+
1.770	8	311	2.010	3	061,351	2.790	5	102,122
1.728	21	222,151	1.972	4	011,401+	2.751	8	141,311
1.709	9	042	1.938	4	261,510	2.723	10	240,330+
1.689	12	321	1.924	13	332,402	2.667	1	321,301+
1.640	9	142,060	1.902	6	132	2.644	2	122
1.609	2	232	1.885	8	202,421+	2.592	3	202,241
1.574	19	331	1.819	3	531,222	2.548	5	112,132+
1.567	13	160	1.797	2	350,261	2.518	2	221,301
1.518	9	340,113+	1.783	4	351	2.488	2	222,212
1.490	3	312	1.768	4	152,171	2.460	2	141
1.464	16	123,152+	1.679	11	352,080+	2.447	1	331
1.456	14	400	1.653	5	152,242+	2.385	5	202,140+
1.418	8	260	1.635	7	600,511	2.340	4	041,132
1.394	1	420	1.599	6	551,532+	2.290	5	222,341+
1.378	3	411,213	1.586	6	550,620+	2.257	5	122,250+
1.344	12	223,071+	1.575	<1	332,081	2.232	<1	132
1.322	2	351,162	1.552	2	531	2.212	1	042
1.299	6	143	1.539	2	281	2.199	1	212
1.279	1	431,342	1.520	2	602,003	2.162	2	400
1.245	3	360	1.501	2	641	2.149	1	232,421
1.233	3	412,053	1.487	2	402	2.127	<1	322,322
1.221	1	271,313	1.475	3	133,622+	2.096	3	401,141
1.214	3	361,243	1.463	3	281,403	2.088	4	350
1.204	2	422,072	1.430	2	352,423+	2.031	<1	234,440+
1.192	5	352,323	1.415	2	551,243+			
1.185	3	014	1.381	2	481,480+			
1.132	1		1.344	10	153,0100+			
1.124	2		1.329	1	353,730+			
1.121	1		1.268	2	751,2101+			
1.109	5		1.225	3	750,2101+			
1.105	3		1.192	1	602,591+			
1.084	1		1.175	2	204,4101+			
1.069	3		1.161					
1.056	1							

many instances where more than 2 sets of planes contribute to the reflection and influence the 2θ angle of reflection.

Data of the Dow Chemical Company reproduced on card #2-0856 in the JCPDS file include 15 lines to $d = 1.26$, while we record 74 lines to $d = 1.463$. Unit cell parameters are $a = 10.248(2)$ Å, $b = 9.586(2)$ Å, $c = 6.962(2)$ Å, $\beta = 97.87(2)^\circ$. These are in good agreement with the

values $a = 10.22 \text{ \AA}$, $b = 9.56 \text{ \AA}$, $c = 6.94 \text{ \AA}$, and $\beta = 97.9^\circ$, reported by Baur and Rao (1967). Intensity measurements yield $I/I_c = 0.871$, while the calculated value is 0.865. The calculated density is 2.342.

Vivianite: $(\text{Fe}_3(\text{PO}_4)_2 \cdot 8\text{H}_2\text{O})$. The sample of vivianite was a single euhedral crystal from the Siglo XX mine, Llallagua, Bolivia. Similar large crystals are grayish green (5 G 5/2) to moderate blue (5 B 5/6).

Data of the Dow Chemical Company reproduced as JCPDS card #3-70 include 31 lines to $d = 1.47$, while we list 59 lines to $d = 1.161$. Indexing on card #3-70 has only a few errors, but extends only to $d = 2.42$, while the reflections tabulated in this report have been indexed to $d = 1.175$.

Unit cell parameters refined from the powder diffraction data are $a = 10.128(4) \text{ \AA}$, $b = 13.431(5) \text{ \AA}$, $c = 4.695(4) \text{ \AA}$, $\beta = 104.68(4)^\circ$. These are in good agreement with the values of $a = 10.08 \text{ \AA}$, $b = 13.43 \text{ \AA}$, $c = 4.70 \text{ \AA}$, and $\beta = 104.5^\circ$ reported by Mori and Ito (1950). The calculated density is 2.696. The observed value for I/I_c is 2.56 while the calculated value is 1.96. Preferred orientation due to the perfect {010} cleavage is difficult to minimize and undoubtedly this will result in significant variations in relative intensities depending on the method of sample preparation. The most intense reflection for vivianite is 020 and, therefore, preferred orientation due to the {010} cleavage may account for the observed I/I_c greater than the calculated I/I_c .

Purpurite (Mn-heterosite): $((\text{Fe}, \text{Mn})\text{PO}_4)$. We attempted to obtain data for the purpurite end of the purpurite-heterosite series. Of the 5 specimens of purpurite-heterosite, all were closer to the heterosite end member of the series. Because of this, a portion of the type purpurite was obtained from the U.S. National Museum of Natural History. The analysis of this sample, however, was also closer to heterosite than to purpurite. Because it was as close as any of the samples to purpurite, X-ray data were obtained and are included under the name Mn-heterosite.

The Mn-heterosite sample is from the Faires tin mine, Kings Mountain, Gaston County, North Carolina (NMNH 93883). The color is very dusky red purple (5 PR 2/2). Chemical analysis yielded 45.9% P_2O_5 , 36.2% Fe_2O_3 , and 16.6% Mn_2O_3 , leading to the approximate chemical formula $(\text{Fe}_{0.68}\text{Mn}_{0.32})\text{PO}_4$. Unit cell parameters refined from the powder data are $a = 5.828(1) \text{ \AA}$, $b = 9.763(2) \text{ \AA}$, $c = 4.776(6) \text{ \AA}$. These are in good agreement with the values $a = 5.83 \text{ \AA}$, $b = 9.79 \text{ \AA}$, and $c = 4.769 \text{ \AA}$ reported for heterosite of composition $(\text{Fe}_{0.65}\text{Mn}_{0.35})\text{PO}_4$ by Eventoff, Martin and Peacor (1972). The calculated density is 3.679 and the calculated value of $I/I_c = 1.25$. Inadequate quantity of material prevented us from obtaining a satisfactory measurement of I/I_c .

Scorzalite: $((\text{Fe}^{+2}, \text{Mg})\text{Al}_2(\text{PO}_4)_2(\text{OH})_2)$. Scorzalite is the Fe end member of the lazulite-scorzalite series. Twelve specimens from the lazulite-scorzalite series, each representing a different collecting locality, were analyzed for Fe and Mg. From these specimens, the 2 nearest to the end-member compositions were chosen for collection of X-ray data. The

specimen of scorzalite is from Pennington County, South Dakota and occurs as clear, dark blue anhedral masses in a matrix of plagioclase. Analysis for Fe and Mg leads to the formula $(\text{Fe}_{0.80}\text{Mg}_{0.20})\text{Al}_2(\text{PO}_4)_2(\text{OH})_2$.

Seventy-four lines to $d = 1.094$ were observed whereas, Pecora and Fahey (1950) (JCPDS card #6-304) list only 32 lines. Indexing on card #6-304 is only to $d = 1.682$ and there are many errors; we have indexed all of the tabulated lines. The experimental data correspond closely with the calculated pattern making unequivocal indexing possible. Unit cell parameters refined from the powder data are $a = 7.156(1) \text{ \AA}$, $b = 7.306(1) \text{ \AA}$, $c = 7.249(1) \text{ \AA}$, and $\beta = 120.59(1)^\circ$. These are in close agreement with the values $a = 7.15 \text{ \AA}$, $b = 7.31 \text{ \AA}$, $c = 7.25 \text{ \AA}$, and $\beta = 120.58^\circ$ reported by Lindberg and Christ (1959). The calculated density is 3.33. The observed value of I/I_c is 0.858, while the calculated value is 1.11. Hubbard et al. (1976) report that calculated reference intensity ratios are typically larger than the experimental values, as we observed for scorzalite. They ascribe the discrepancies to such factors as peak overlap, preferred orientation, microabsorption, and primary extinction. Peak overlap and preferred orientation are probably not significant in this instance.

Lazulite: $(\text{Mg}, \text{Fe}^{+2})\text{Al}_2(\text{PO}_4)_2(\text{OH})_2$. Lazulite is the Mg end of the lazulite-scorzalite series. The specimen of lazulite is from Werfen, Austria. The mineral is sky blue and occurs as dull anhedral masses in a quartz matrix. Analysis for Fe and Mg leads to the formula $(\text{Mg}_{0.88}\text{Fe}_{0.12})\text{Al}_2(\text{PO}_4)_2(\text{OH})_2$.

The data presented here are more complete and more accurate than those of Campbell (1962) reproduced on JCPDS card #14-137. Card #14-137 lists only 36 lines to $d = 1.274$ and there are many indexing errors. We show 66 lines to $d = 1.094$ and these correlate well with the calculated pattern. Unit cell parameters refined from the powder data are $a = 7.151(1) \text{ \AA}$, $b = 7.271(1) \text{ \AA}$, $c = 7.235(1) \text{ \AA}$, and $\beta = 120.55(1)^\circ$. These are in close agreement with the values $a = 7.16 \text{ \AA}$, $b = 7.26 \text{ \AA}$, $c = 7.24 \text{ \AA}$, and $\beta = 120.67^\circ$ reported by Lindberg and Christ (1959). The calculated density is 3.14. The observed value for I/I_c is 1.38, while the calculated value is 1.17.

ACKNOWLEDGMENTS—Calculation of the powder diffraction patterns and refinement of unit cell parameters was done with facilities of the Northeast Regional Data Center of the State University System of Florida. The Joint Committee on Powder Diffraction Standards - International Centre for Diffraction Data provided partial financial support through a grant-in-aid. The Division of Sponsored Research of the University of Florida provided partial funding.

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Florida Sci. 43(4):257-265. 1980.

PRODUCING A COMPREHENSIVE PLAN: PRACTICING ANTHROPOLOGY IN THE PLANNING PROCESS—C. Martin Banspach, Department of Anthropology, University of South Florida, Tampa, Florida 33620

ABSTRACT: *In 1975, the Florida Legislature adopted the "Local Government Comprehensive Planning Act". This act requires all counties and municipalities to create a comprehensive plan to guide future urban development. I discuss the application of anthropological techniques and skills to the production of a comprehensive plan. I demonstrate the integration of ethnography and ethnoscience into the urban planning process. The perspective of this report is that of an interdisciplinary approach, as practiced through a private consulting firm.*

THE Local Government Comprehensive Planning Act was passed by the Florida Legislature in 1975, as a means of upgrading and coordinating local and regional land management programs to be consistent with state policies. The Act mandates that each unit of local government, as part of a continuing planning program, prepare and adopt a comprehensive plan by 1 July 1979 (Starnes, 1979).

The comprehensive plan must include several required elements. However, the Act encourages planning based on local issues and perspectives, utilizing input from local citizens during plan preparation. The content of the plan should reflect the community's goals and objectives concern-

ing future growth and development (Florida Department of Community Affairs, 1976).

At the time the Act was passed, many rural counties and small municipalities were unprepared to comply with the planning requirements; often lacking the expertise and/or sufficient manpower to accomplish the task. One approach which has been frequently used to solve this problem is for the rural local government to contract with a private consulting firm to provide the temporary services and expertise necessary for producing a comprehensive plan.

As a Senior Associate with a Tampa-based consulting firm, I have been directly involved, for more than a year, with the development of comprehensive plans for 2 rural Florida counties. These 2 agriculturally-oriented counties, both bordering on Lake Okeechobee, have each contracted with my firm to produce their comprehensive plans in conformance with state legislation. Working on these contracts as a consultant has provided me with a valuable opportunity for utilizing the anthropological approach as an integral part of the planning process.

An interdisciplinary team approach is being applied to the preparation of the 2 comprehensive plans. The planning team is composed primarily of myself and a more traditional land use-oriented planner. An economist was also brought in during the initial stages of the plan development to perform an economic assessment for each of the 2 counties.

The comprehensive planning process, which defines the work strategies for plan development, was the result of a collaborative design combining conventional physical planning, state mandated procedures, and applied social planning. The social planning procedures resemble the methods devised by Herbert Gans, which he described as "goal-oriented planning" (Gans, 1968).

The following outline identifies the 5 planning stages of the planning process and the major work tasks associated with each stage.

The Comprehensive Planning Process

1. Determine and Analyze existing situation.
 - a. Inventory
 - b. Assess current situation
 - c. Estimate future situation
 - d. Identify local needs
2. Identify Preliminary goals and objectives.
 - a. Identify community desires
 - b. Outline basic assumptions
3. Develop alternative policies to achieve goals/objectives.
4. Evaluate alternative policies in terms of:
 - a. Costs
 - b. Effectiveness
 - c. Local acceptability
5. Specify implementation programs.
 - a. Select appropriate programs
 - b. Where necessary, identify economic feasibility of actions required by programs

Various anthropological methods and techniques were found to be effective planning tools when integrated into the comprehensive planning process.

The initial stage in the planning process is similar in nature to an holistic, ethnographic study; the objective is to discover and understand the existing situation of the county. Aggregate data published by state and regional agencies are useful, but to understand the local situation, local data must be collected and examined. The responsibilities of other contracts and the distance separating the consultants from the counties under study precluded the frequency of local visits by the consultants to no more than 4 da a mo. Traditional ethnographic techniques would not be productive in this situation.

One solution to this problem was the systematic examination of the weekly newspapers from each county, sent to the Tampa Office. Anthropologists working within an urban setting commonly utilize newspaper clippings as a standard research tool (Eiselein and Topper, 1976). The use of newspapers and other media enable the anthropologist to study "culture at a distance" as demonstrated in the handbook edited by Mead and Metraux (1953).

Another method of local data collection utilized by the consultant team was the ethnoscientific approach. Ethnoscience was used in an attempt to reveal the interrelationships of the issues and problems within the 2 counties. The method, adopted from Spradley (1972), involved the use of elicitation strategies during formal, as well as informal, interviews with local informants. The results of the analysis often were used to define the appropriate goals and objectives for each locality.

The use of anthropological skills and techniques are especially advantageous to an urban planner working in a rural area. Rural-urban cultural differences are significant, especially in relation to attitudes concerning land planning (Sargent, 1976). An applied anthropologist, who views the world from a cultural relativistic perspective, will normally have the advantage over a conventional planner in terms of the ability to more accurately assess the local community's issues and perspectives.

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Florida Sci. 43(4):265-268. 1980.

Biological Sciences

LIGHT EXPOSURE AND SOLUBLE SUGARS IN CITRUS FROST HARDINESS¹

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ABSTRACT: 'Valencia' orange, *CITRUS SINENSIS* (L.) Osb., accumulated sugars and cold-hardened when exposed to light and a constant 10C for 28 da. Sucrose was the primary sugar accumulated, with concentrations exceeding 60 mg/gm of leaf dry weight. Sucrose accumulation was closely correlated with the onset of frost hardening.

THE extent to which citrus is injured by a mild frost is dependent on weather conditions preceding freezing temperatures (Yelenosky and Young, 1977). If days are hot and nights warm, a mild freeze is capable of causing injury to citrus trees. However, if days are cool and nights cold, the trees are able to acclimate and increase their resistance to freeze injury (Young, 1961).

Proper inductive temperatures and light exposure are required for citrus to fully acclimate (Young, 1969; Yelenosky, 1971, 1975). Young (1969) found that young, potted grapefruit trees did not cold-harden at low temperatures without light. Yelenosky (1971) showed further that, if kept in the dark for 7 da, citrus seedlings lose their frost hardiness at low temperatures.

Present evidence suggests that products of photosynthesis stimulate frost hardiness in a quantitative manner. Increased frost hardiness has been associated with longer daylength during cold-hardening of citrus (Nijjar and Sites, 1959). The response to longer daylength suggests that photosynthate production contributes to cold hardening. Longer daylength during low temperature hardening has been shown to increase frost hardiness in plant species other than citrus (Dexter, 1933; McGuire and Flint, 1962). Recently, Mikaberidze (1975) has shown that frost-hardy citrus cultivars exhibit a

¹A portion of a thesis submitted by C. L. Guy as partial requirement for the Master of Science degree in the Department of Biological Sciences, University of Central Florida, Orlando, Florida 32816. Mention of a trademark, proprietary product, or vendor does not constitute a guarantee or warranty by the U.S. Department of Agriculture and does not imply its approval to the exclusion of other products or vendors that may also be suitable.

higher photosynthetic rate than frost-sensitive varieties during the winter. In addition, Yelenosky (1975) demonstrated that a reduction in leaf area (by defoliation) before exposure to cold hardening temperatures with light resulted in less acclimation.

Sugars accumulate in the tissues of citrus trees during acclimation (Ivanov, 1939; Young and Peynado, 1965; Young, 1969; Yelenosky and Guy, 1977). Cold-hardy tissues are characterized by a high sugar content. However, maximum sugar concentration does not always coincide with maximum frost hardiness. Previous reports on the relationship between sugar concentration and freezing resistance are inconclusive (Young and Peynado, 1965; Young 1969, Yelenosky and Guy, 1977). Whether sugars are truly related to citrus frost hardiness remains to be shown. We attempted to correlate light exposure and photosynthetic sugar accumulation with frost hardiness in 'Valencia' (*Citrus sinensis* (L.) Osb.) orange seedlings.

MATERIALS AND METHODS—Controlled environment chambers were used for conditioning experiments as described by Yelenosky (1975). A constant acclimation-inducing temperature of 10 C was chosen for cold-hardening experiments. Light was supplied for 12 hr/per da by 40 1500 mA fluorescent cool-white tubes and 16 100-W incandescent bulbs, giving a light intensity at plant height of 80.7 nE cm⁻²sec⁻¹. Trees were conditioned for up to 28 da. Frost hardiness was determined by freezing the seedlings in a controlled environment chamber as described by Yelenosky and Guy (1977). A standard -7 C freeze for 4 hr was used for cold-hardiness determinations.

'Valencia' orange seedlings were grown from seed under greenhouse conditions in a peat moss and sand mix in plastic pots.

Uniform seedlings were selected and cold hardened in the controlled environment chamber. Aluminum foil was placed over the leaves of half the trees to prevent light exposure and photosynthesis. The stems were not covered by the foil and were exposed to light during cold hardening. The trees were conditioned for 0, 7, 14 or 28 da at 10 C and then frozen to determine frost hardiness. Three trees from each treatment were selected at the same intervals for carbohydrate analysis.

Leaf and stem tissue samples were dried at 90 C for 90 min and then at 70 C for 22 hr. The dried samples were then ground with a Wiley mill to pass through a 40-mesh screen. Samples were then extracted with 76% ethanol for 6 hr. After removal of the ethanol by evaporation in a rotary evaporator, sugars were purified by ion exchange resins (Williams et al., 1950). Total sugars were measured by the anthrone method (Plummer, 1971). Reducing sugars were determined by the Somogyi-Nelson method (Hodge and Hofreiter, 1964). Sucrose content was calculated by subtracting reducing sugars from total sugars. Standard curves for the anthrone and Somogyi-Nelson determinations were made with glucose.

Starch was extracted by boiling the ethanol-insoluble residue in 10 ml distilled water for 15 min. After cooling, 10 ml of 0.5% w/v amyloglucosidase (Sigma) in 0.2 M citrate buffer at pH 4.5 was added. The

mixture was incubated for 2 hr at 55 C. The resultant glucose content was determined with glucose oxidase obtained from Worthington Biochemicals.

Percentage data were transformed to arcsin prior to statistical analysis.

RESULTS—Frost injury of both the leaves and stem tissues was reduced by conditioning plants while exposed to light (Table 1). Citrus leaves that were covered with aluminum foil during cold-hardening regimes did not acclimate (100% injury), but the light-exposed stem tissue showed some hardening.

When leaves were exposed to light at 10 C, their leaf and stem carbohydrates increased markedly. Total sugars (Figs. 1 and 2A) and reducing sugars (Figs. 1B and 2B) approximately doubled, while sucrose (Figs. 1C and 2C) increased between 3 to 4 fold. The starch content of leaves more than doubled while concentrations in the stem appeared to remain unchanged during acclimation. Trees that had foil-covered leaves during hardening treatments showed very small changes in carbohydrate levels, a phenomenon which may reflect experimental variability rather than actual changes. Starch in the leaves, however, declined to a very small percentage of its level before darkness.

DISCUSSION—‘Valencia’ orange seedlings acclimate well when exposed to low temperatures (10 C) accompanied by high-intensity white light. These results demonstrate that light is needed to fully stimulate maximum cold hardiness in citrus and are in agreement with the work of Yelenosky

TABLE 1. Average percent injury to ‘Valencia’ orange seedlings frozen at -7 C after cold hardening at 10 C, with and without leaves exposed to light.

Days of 10 C	Seedlings with leaves covered with aluminum foil		Seedlings with no cover over leaves	
	Leaf kill	Stem kill	Leaf kill	Stem kill
0	100 a*	100 a	100 a	100 a
7	100 a	83 b	83 b	45 c
14	100 a	56 c	39 c	15 e
28	100 a	38 d	8 d	0 f

*Means followed by different letters are significant at the 5% level, Duncan's multiple range test.

TABLE 2. Correlation coefficients (r) of major sugar fractions associated with freeze injury of ‘Valencia’ orange seedlings at -7 C.

Sugars	Leaves	Stems
Sucrose	-0.894	-0.945
Reducing sugars	-0.721	-0.265
Total sugars	-0.866	-0.860

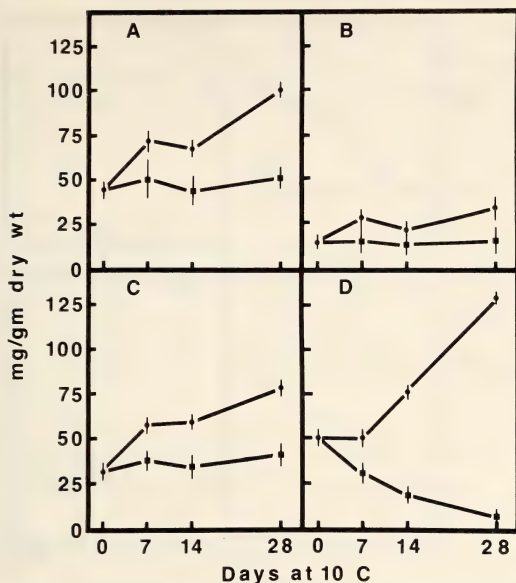


FIG. 1. Effect of constant 10 C on various carbohydrate fractions in leaves of 'Valencia' orange seedlings: A - total sugars; B - reducing sugars; C - sucrose; D - starch. (■) = Leaves covered with aluminum foil; (○) = leaves not covered.

(1975) and Young (1969). The mechanism by which light stimulates cold acclimation is unknown, although it is presumed that light's action is photosynthetic and that manufactured products somehow result in frost hardiness. This appears correct in citrus, because illuminated trees contain higher amounts of sugars and are more hardy than trees not exposed to light. In this study, illumination resulted in more cold hardening of green stems when leaves were uncovered than when covered with aluminum foil (Table 1).

Comparison of sugar concentration vs. frost injury showed a strong association between soluble sugars and citrus frost hardiness (Table 2), with sucrose being most highly correlated; reducing sugars were poorly correlated, whereas total sugars (i.e., reducing sugars and sucrose) showed an intermediate correlation. Data suggest that maximum concentrations of sugars coincide with maximum frost hardiness in citrus tissues. This association is not as evident in all studies (Young, 1969; Yelenosky and Guy, 1977). Steponkus (1971) provided some direct evidence that sucrose participates in the hardening process by demonstrating increased acclimation when ivy tissues were infused with a 50 mM sucrose solution.

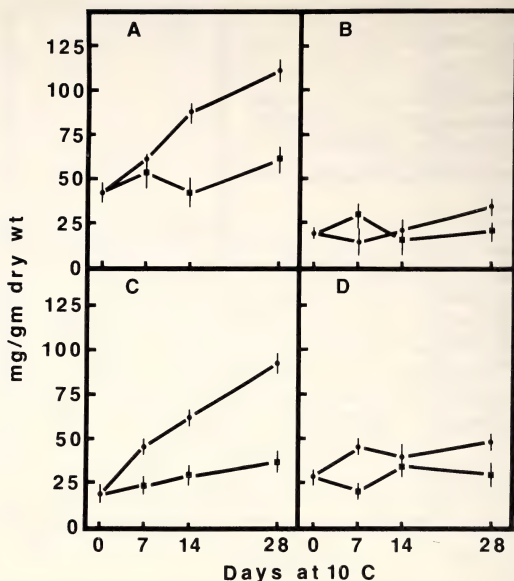


FIG. 2. Effect of constant 10 C on various carbohydrate fractions in stems of 'Valencia' orange seedlings: A - total sugars; B - reducing sugars; C - sucrose; D - starch. (■) = Leaves covered with aluminum foil; (●) = leaves not covered.

Although sucrose is closely correlated with 'Valencia' orange cold hardiness, no indication of how the sugar could enhance frost hardiness is provided by these data. One possibility is that the accumulation of sugars increases the osmotic potential of the cell sap, thereby lowering its freezing point while reducing the amount of cellular dehydration caused by extracellular ice formation. However, if the mechanism were osmotic, total sugars should show a higher correlation with hardiness than did sucrose. Sucrose is a known cryoprotectant, and, as it accumulates, most frost-sensitive sites may become protected, resulting in increased frost hardiness (Heber et al., 1973).

The action of sucrose may be indirect. An intriguing theory is that it is sucrose which acts at the genetic level to induce acclimation. Sugars are known to influence gene expression in bacteria (Watson, 1976), and there has been at least 1 demonstration of enzyme induction by high sucrose levels in higher plants (Chin and Weston, 1975; Weston and Chin, 1975). Further, the accumulation of sucrose is universal to plants during cold-induced acclimation, and if prevented from synthesizing sucrose (i.e., by being held in

the dark), acclimation cannot occur. Finally, since Sakai and Yoshida (1968) have demonstrated that an increase of internal sucrose concentration precedes hardening of black locust, while decreases precede dehardening, there is enough evidence to justify further searches for a sucrose-regulated hardiness gene(s).

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TWO DIFFERENCES OF THE VALVES OF BRACHIOPODS AND PELECYPODS

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ABSTRACT: *Asymmetrical sculpture on a valve is much rarer in brachiopods than in pelecypods. The reason for this difference seems to be that pelecypods are primarily burrowers but few brachiopods burrow. The asymmetrical sculpture on the valve of a pelecypod aids the animal in gripping the sediment while it burrows. In brachiopods the beaks of the 2 valves lie at the center of the posterior margin and point directly toward each other. In pelecypods the beaks most commonly point anteriorly, although many have beaks pointing toward each other and a few have the beaks pointing posteriorly. Anteriorly pointing beaks may also be an adaptation that aids a pelecypod in burrowing.*

THE difference in the planes of symmetry of the valves of brachiopods and pelecypods has been pointed out by Shrock and Twenhofel (1953). In the brachiopods the plane of symmetry is generally through the valves, and a line drawn from the beak to the opposite or anterior margin of a single valve divides the valve into 2 equal halves. In other words, a brachiopod valve is commonly equilateral, although the 2 valves of a specimen are generally of different size and shape (i.e., inequivalved). Furthermore, the viscera of a brachiopod are arranged so that a line drawn from the beak to the opposite margin through the valves will cut the viscera into 2 equal halves. On the other hand, the plane of symmetry in pelecypods is between the 2 valves and normally the valves are of equal size and shape, although there are a considerable number of pelecypods that are inequivalved. The viscera also have this plane of symmetry; the left half of the viscera is in the left valve and the right half of the viscera is in the right valve. The valves of pelecypods are almost always inequilateral, which is just the opposite from the brachiopods. The differences in the symmetry of both valves and viscera between brachiopods and pelecypods may partially account for differences in the symmetry of the sculpture on the valves and also differences in which direction the beaks point in the 2 groups. Moreover, basic differences in symmetry and sculpture are linked to different habitats occupied by the 2 groups of animals. At least 70.0% of all species of pelecypods are infaunal (Nicol, 1968), whereas only about 1.0% of all brachiopods (the lingulids) are infaunal.

SCULPTURE OF THE VALVES—Megascopic sculpture in pelecypods and brachiopods consists of ribs, nodes, rugae, and spines and is common on the shells of both groups of animals, although some brachiopods and pelecypods are devoid of sculpture. An examination of the various types of sculpture in these 2 groups reveals many similarities, but there are also some striking differences. Radial ribs in brachiopods run from the beaks to the opposite or

anterior margin, and radial ribs in pelecypods run from the beaks to the opposite or ventral margin. Concentric ribs in brachiopods run from the right to the left side of each valve, whereas concentric ribs in pelecypods run from the anterior to the posterior margins. The sculpture of brachiopods consists predominately of radial ribs. Concentric ribs are more common in pelecypods, although radial ribs are also common in this group.

In most brachiopods that have sculpture, there are radial ribs that radiate from the area of the beaks to the opposite margin. The sculpture is generally symmetrical as viewed from either the pedicle or brachial valve. This symmetrical arrangement of the ribs is also seen on many pelecypods, but there are many exceptions. In Fig. 1 A, the pelecypod has concentric ribs on the anterior and central part of the valve, but radial ribs occur on the posterior part of the valve. In Fig. 1 B, the typical symmetrical arrangement of the radial ribs of a brachiopod is apparent. The asymmetrical arrangement of the ribs of the pelecypod seen in Fig. 1 A is rarely found in any living or fossil brachiopod; however, it is quite common in many different families of pelecypods.

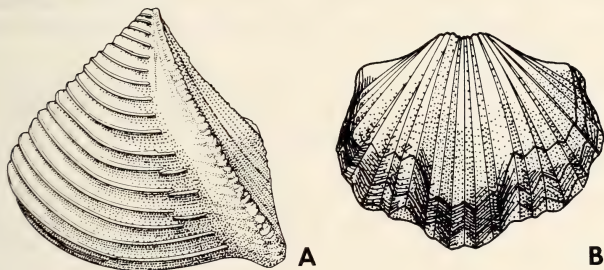


FIG. 1. A. Pelecypod with asymmetrical ribbing. B. Brachiopod with symmetrical ribbing.

Stanley (1970, 1977) and Saul (1978) have noted that the asymmetrical sculpture of knobs and ridges on the valves of pelecypods is commonly associated with burrowing or mechanical boring. In trigoniids and other infaunal groups of pelecypods, the asymmetrical sculpture aids in gripping the sediment as the animal burrows into it. Because very few brachiopods are burrowers, asymmetrical sculpture is not a needed adaptation. Asymmetrical ribbing in pelecypods comes in a variety of forms; some of these will be described.

In a few pelecypods, the concentric sculpture is chevron-shaped, and some examples are seen in several unrelated genera of pelecypods, such as *Acila* (Nuculanidae), *Gafrarium* (Veneridae), *Strigilla* (Tellinidae), *Divaricella* (Lucinidae), and *Amblema* and *Chevronaias* (Unionidae). The chevron-shaped ribs may be either anterior or posterior to the center of the

valve. Chevron-shaped markings do occur along the anterior margin of the valves of some brachiopods, but they seem to be related to the folded margin of the commissure between the valves. However, these chevron-shaped markings are symmetrically-arranged in brachiopods.

Less common than chevron-shaped ribs are V-shaped ribs in pelecypods. The latter type of ribbing occurs in *Goniomya* and *Pentagrammesia* (Pholadomyidae), *Trigonioides*, *Iotrigonia*, and *Vaugonia* (Trigoniidae), and *Scabies*, *Nipponaia*, *Ecuadoria*, and *Prodiplodon* (Unionidae). *Triplodon*, also a unionid, has both chevron-shaped and V-shaped ribs on a single valve. I have not seen this type of ribbing on any brachiopods. The chevron-shaped and V-shaped ribs are sometimes called divaricate ribs by paleontologists and malacologists. Chevron-shaped and V-shaped ribs appear to be found only in pelecypods that burrow into sediment.

In a few instances, the concentric ribs of burrowing pelecypods, such as *Scissula*, *Grammatomya*, and some species of *Amblema*, are oblique. In *Grammatomya* the oblique concentric ribs cover the anterior three-fourths of the valve; the posterior one-fourth of the valve has radial ribs. Keen (1971) refers to these ribs as diagonal in describing *Strigilla* (*Simplistrigilla*) *serrata* Mörch. This type of ribbing is most common in tellinacean pelecypods. *Kulumbella* and a few other brachiopods have oblique rugae (Moore, 1965).

Strikingly different sculpture on the pedicle and brachial valves of brachiopods (particularly amongst the productaceans) and on the right and left valves of inequivalved pelecypods is well-known. Some of the rudist pelecypods have completely different sculpture on the right and left valves.

In some pelecypods there is a marked difference in sculpture in the early growth stages of the shell and the adult or later stages, as for example in *Arcinella*, *Hinnites*, and *Penicillus* (Moore, 1969). This change in sculpture and often in shell shape is associated with a change in life habits during ontogeny. Križ (1979) has described abrupt changes in sculpture on the valves during ontogeny of many species of the Silurian pelecypod family Cardiolidae. One of the strangest changes in sculpture occurs on *Ilymatogyra* Stenzel of the superfamily Ostracea. The early stage of the shell of the left valve is smooth, and this is followed by a stage where there are wrinkled dichotomous radial ribs. The adult shell is again smooth (Moore, 1971). Such abrupt changes in sculpture during the ontogeny of a brachiopod is certainly not nearly so common as it is in pelecypods. From this brief review of the comparison of sculpture in brachiopods and pelecypods, one sees that the sculpture is much more variable in pelecypods than in brachiopods.

ORIENTATION OF THE BEAKS—Another common difference between the symmetry of brachiopods and pelecypods can be seen on the outside of the valves of these 2 groups. In brachiopods the beaks point toward each other and are located at the center of the posterior margin (Fig. 2 D); this would



FIG. 2. C. Pelecypod with typical prosogyrate beaks. D. Brachiopod with typical orthogyrate beaks.

be called orthogyrate in pelecypod terminology. In pelecypods the beaks may point directly toward each other as in brachiopods, but they are not commonly located exactly at the center of the dorsal margin. More frequently the beaks point anteriorly in pelecypods and this orientation is referred to as prosogyrate (Fig. 2 C). Stanley (1975, 1977) noted that prosogyrate beaks in pelecypods enhance burrowing, particularly so in forms where the valves are markedly convex. By far the least common orientation seen in pelecypods is for the beaks to be pointed posteriorly, and this is termed opisthogyrate. Textbooks on invertebrate paleontology do not mention these differences between the pelecypods and brachiopods concerning the location of the beaks and the direction they point.

An examination of pelecypod specimens in the mollusc collection at The Florida State Museum indicates that about 55.0% of all living pelecypods have prosogyrate beaks, about 35.0% have orthogyrate beaks, and no more than 10.0% have opisthogyrate beaks. Some families and superfamilies are consistent as to the direction the beaks point, whereas others are not. The Mytilidae, Veneridae, and Chamidae have consistently prosogyrate beaks, whereas the Pectinidae and Limidae have consistently orthogyrate beaks. Most arcaceans have orthogyrate beaks, but many have prosogyrate beaks and a few have opisthogyrate beaks. In the Ostreidae the beaks are commonly opisthogyrate. In some specimens of the Spondylidae, the left valve has an orthogyrate beak, but the right valve has an opisthogyrate beak. There does not appear to be a close correlation between living habits and the direction in which the beaks point. Most burrowing pelecypods have prosogyrate beaks, but some have orthogyrate beaks, and a few have opisthogyrate beaks. Some byssate groups have prosogyrate beaks; others have orthogyrate beaks. Shell-cemented species may have prosogyrate, orthogyrate, or opisthogyrate beaks. Similarities in beak orientation coupled with shell shape may arise from totally different ancestors. As an example, it is my opinion that *Glossus* and *Meiocardia*, both of which are very convex and have strongly prosogyrate beaks, are unrelated. But not only are they placed in the same family in the classification in the *Treatise on Invertebrate Paleontology* (Moore, 1969); they are also placed in the same genus and are

given only subgeneric rank. The hinge teeth of *Glossus* and *Meiocardia* are quite different, which makes me believe that these 2 genera arose from entirely different stocks.

The primary reason the pelecypods have a more variable sculpture and a much more variable location and orientation of the beaks than the brachiopods is that the pelecypods are mostly infaunal and burrowers and the brachiopods are not.

ACKNOWLEDGMENTS—I am indebted to Ms. Jeanne Trudeaux of the Office of Instructional Resources at the University of Florida who made the drawings for Fig. 1 and to Ms. Esta L. Belcher of the Zoology Department at the University of Florida who made the drawings for Fig. 2.

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Florida Sci. 43(4):274-278. 1980.

ABRASION RATES OF CERTAIN MARINE SHELLS AND CORALS

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ABSTRACT: *Shells from the reef shoal environment were abraded in different experiments. These experiments were conducted in the surf zone to a quartz sand beach, a carbonate beach, a wave tank, and a tumbling machine. Abrasion rates were also measured on certain corals using a tumbling machine with sand-size carbonate grit. The results of these experiments showed an expected low breakdown of particles using carbonate grit than quartz sand and chert pebble, and that abrasion may be the major factor of breakdown in the back-reef open sand zone.*

ABRASION experiments are important to understand the breakdown of skeletal material in marine environments, and to determine the correspondence between fossil and existing communities. Abrasion, in contrast to fracturing, transforms coarse particles into very fine rather than intermediate sized grains (Chave, 1960). Previous work in the area of shell abrasion has been done mainly in the laboratory by tumbling shells with chert pebbles or quartz sand (Chave, 1960, 1964), or in the field in a quartz sand environment (Driscoll, 1967, Force, 1969). Chave (1964) determine that smaller and lighter shells are broken down more rapidly than are massive forms. Driscoll (1967) examined the abrasion effects on pelecypods in the surf zone of a quartz beach in Massachusetts. He found that species with more surface area per unit weight of the shell reduced more rapidly on a percentage basis, but those with less surface area lose more shell material in absolute terms.

Rates of abrasion depend not only on the skeletal microarchitecture, but on the abrasive used. Chave (1960, 1964) used chert and quartz sand in a tumbling barrel on various carbonate components and obtained much faster rates of abrasion than obtained in this study. Milliman (1974) used only carbonate components and found rates of abrasion about 2 orders of magnitude slower than those using quartz grit. Echinoids, barnacles, and *Halimeda* degraded rapidly, while coral and mollusk fragments took much longer.

In this study, the experiments were conducted in a wave tank and tumbling barrel with wet carbonate sediment as grit. Detailed examination of the abrasive effect on certain components was made using the scanning electron microscope (SEM).

Four species of mollusk shells common in the reef shoal environment were used in all abrasion experiments: *Cyphoma gibbosum* Linne (Fig. 1),

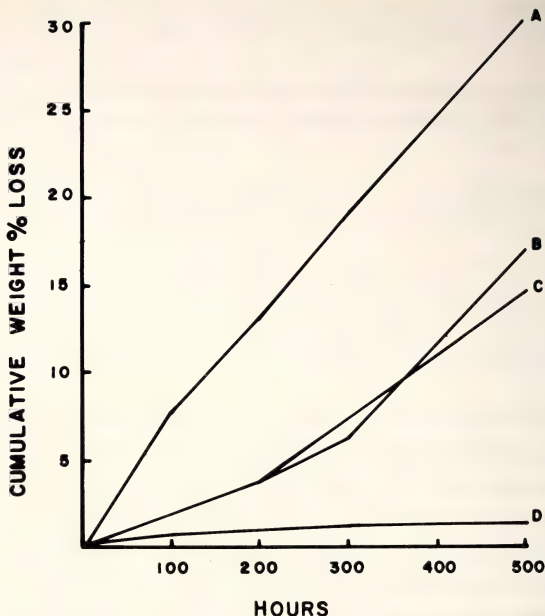


FIG. 1. A comparison of the various abrasion rates of the gastropod *Cyphoma gibbosum* obtained from different experiments. A = surf zone at Alligator Point, Florida; abrasive was quartz sand; wave height 10 cm; wave period 3 sec. B = tumbling barrel at 30 rpm; carbonate sand as a grit. C = surf zone at Bahia Honda, Florida Keys; abrasive was carbonate sand; wave height 10 cm; wave period 3 sec. D = wave tank; carbonate sand as a grit; wave height 3 cm; wave period 2 sec.

Bulla striata Bruguiere (Fig. 2) *Glycymeris pectinata* Gmelin (Fig. 3), and *Chione cancellata* Linne (Fig. 4). All specimens were obtained live. The shells were weighed, placed on a layer of sand-size carbonate sediment, and covered with sea water to a depth of 6 cm. The waves generated were of sufficient energy to suspend only particles of less than sand-size into suspension. The shells were removed after a certain number of hours, reweighed, and the service marks examined under the SEM. The results (Fig. 1) show that the abrasion rate in the wave tank is one-third slower than that observed in the field experiments in the surf zone at Alligator Point in the Florida Panhandle and those observed at Bahia Honda in the Florida Keys. At both areas, the wave-energy level was similar at the time the experiments were

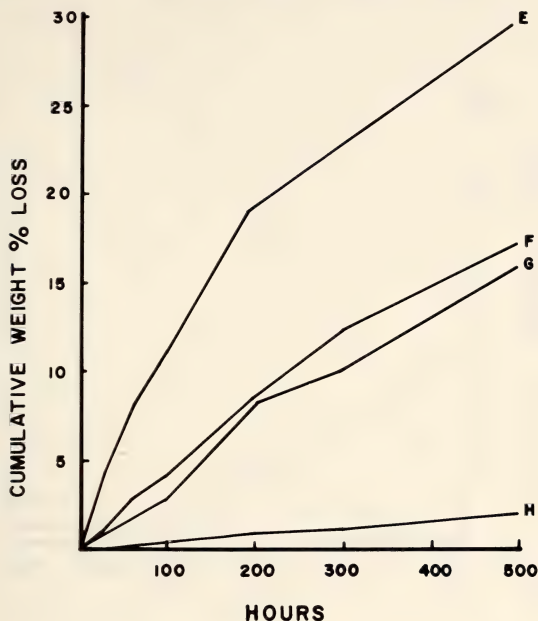


FIG. 2. A comparison of the various abrasion rates of the gastropod *Bulla striata* obtained from different experiments. E = surf zone at Alligator Point, Florida; abrasive was quartz sand; wave height 10 cm; wave period 3 sec. F = tumbling barrel at 30 rpm; carbonate sand as a grit. G = surf zone at Bahia Honda, Florida Keys; abrasive was carbonate sand; wave height 10 cm; wave period 3 sec. H = wave tank; carbonate sand as a grid; wave height 10 cm; wave period 2 sec.

carried out. Weighed shells were fixed to a line and attached to the sea flood with metal stakes. One shell of each genus was removed every 25 hr at Alligator Point and every 12 hr at Bahia Honda. Each shell was reweighed and examined under the SEM. The experiment made at Alligator Point was subject to quartz sand abrasion and the results agree very closely with those obtained by Force (1969). The data obtained from experiments conducted off the beach at Bahia Honda represented a carbonate sand abrasion; it was found that these rates were very much slower.

Other tumbling experiments were carried out on pebble-size pieces of 4 common species of coral, *Millepora complanata*, and whole echinoid tests. The results of these experiments are in Fig. 5 and agree with those given by

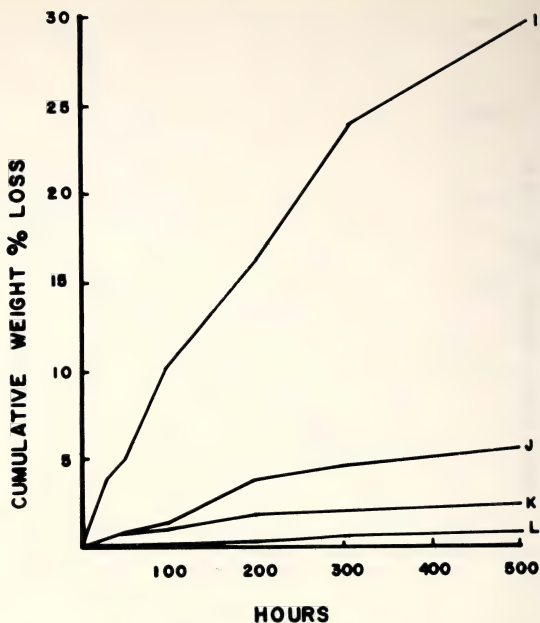


FIG. 3. A comparison of the various abrasion rates of the pelecypod *Glycymeris pectinata* obtained from different experiments. I = surf zone at Alligator Point, Florida; abrasive was quartz sand; wave height 10 cm; wave period 3 sec. J = tumbling barrel at 30 rpm; carbonate sand as a grit. K = surface zone at Bahia Honda, Florida Keys; abrasive was carbonate sand; wave height 10 cm; wave period 3 sec. L = wave tank, carbonate sand as a grit; wave height 10 cm; wave period 2 sec.

Milliman (1974). Similar experiments carried out by Chave (1964), using chert pebbles, showed that approximately 50% of *Acropora palmata* greater than 4 mm remained after 25 hr of tumbling. The results presented here using carbonate sand grit show that over 98% remained after a similar time period. Similarly, echinoids were completely abraded after approximately 7 hr using chert pebbles, whereas in these experiments it took nearly 90 hr.

These results with carbonate sand show an overall slower breakdown of the surface of the shells than with quartz sand and chert pebbles, as would be expected. It was also found that for abrasion to occur, it is necessary that there be a slurry-like mixture similar to wet concrete mix. To obtain this slurry, and thereby abrasion, it is necessary to have silt and clay size particles

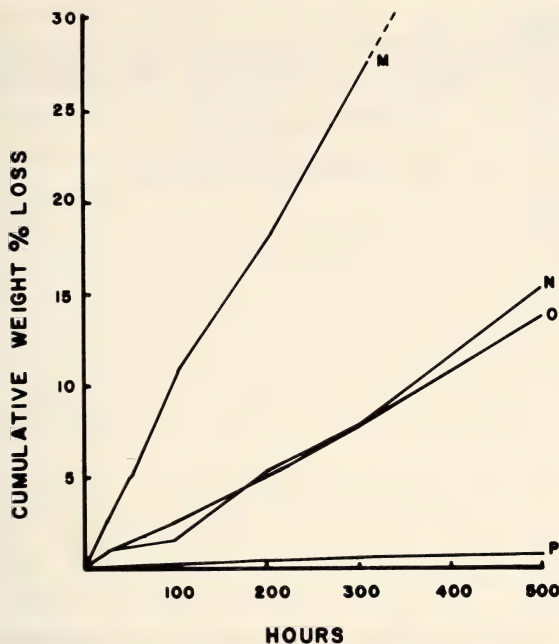


FIG. 4. A comparison of the various abrasion rates of the pelecypod *Chione cancellata* obtained from different experiments. M = surf zone at Alligator Point, Florida; abrasive was quartz; wave height 10 cm; wave period 3 sec. N = tumbling barrel at 30 rpm; carbonate sand as a grit. O = surf zone at Bahia Honda, Florida Keys; abrasive was carbonate sand; wave height 10 cm; wave period 3 sec. P = wave tank; carbonate sand as a grit; wave height 10 cm; wave period 2 sec.

present. I believe that these fine particles increase the viscosity, or "stickiness," so that the larger particles will carry the smaller ones around with them as they rub together. This observation may have some meaning when applied to the reef shoal environment. The breakdown of particles in the reef crest and back-reef rubble zones may be due predominantly to storm-wave-induced fracturing and bioerosion, whereas in the open sand zone, where there are very fine particles, abrasion may dominate.

ACKNOWLEDGMENTS—This study has been made possible by the help, advice, and participation of many people, especially S. W. Wise, W. F. Tanner, J. Osmond, and R. Mariscal of Florida State University at Tallahassee, Florida. This paper is published with the permission of Amoco Production Company, but the views expressed herein are not necessarily coincident with those of Amoco Production Company.

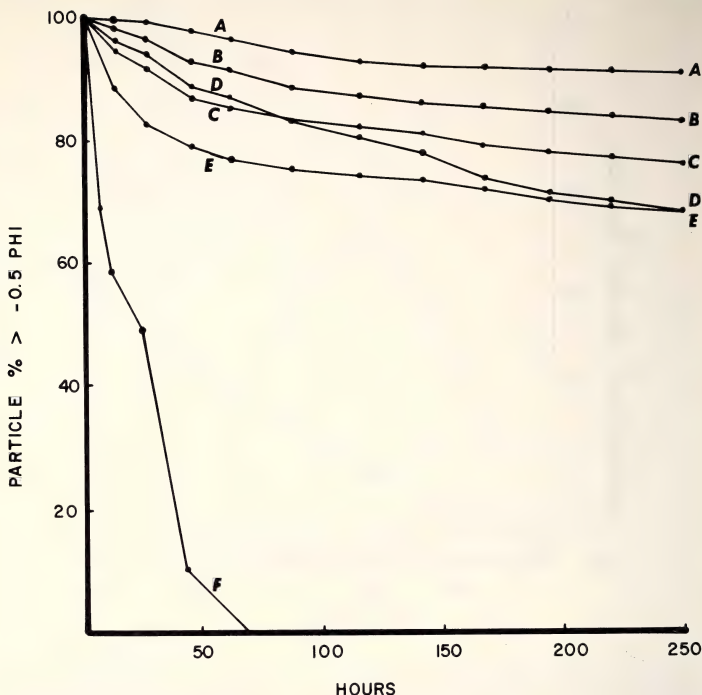


FIG. 5. A graph of the tumbling experiments (at 30 rpm) showing the abrasion rates of certain greater than -0.5ϕ size specimens. A = *Manicina areolata*. B = *Acropora palmata*. C = *Porites porites*. D = *Millepora complanata*. E = *Acropora cervicornis*. F = *Diadema antillarum*.

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YIELD AND WATER USE OF VEGETABLE CROPS WITH SEEPAGE AND DRIP IRRIGATION SYSTEMS¹

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ABSTRACT: *Experiments were conducted in the spring of 1978 to compare the effect of seepage and drip irrigation on the yield of broccoli (BRASSICA OLERACEA L., Italica Group cv. 'Green Comet Hybrid'), sweet corn (ZEA MAYS cv. 'Silver Queen') and zucchini squash (CUCURBITA PEPO cv. 'Fordhook'). Fertilizer rates were 2.77 kg N, 1.07 kg P, 3.8 kg K, and 0.3 kg Mg/100 row m in both irrigation systems. Seepage irrigated plots received water at a constant rate of 13.31 l/m²/da, while the amount of water with the drip system was adjusted every 10 da throughout the growing season. During their respective growing seasons broccoli received 752 l of water/m² in seepage and 216 l/m² in drip irrigation, sweet corn received 978 l/m² and 355 l/m² and zucchini squash 1124 l/m² and 359 l/m². Broccoli had a higher per plant and per ha yield with seepage irrigation. Sweet corn and zucchini had a higher/ha yield with drip irrigation due to higher plant density/ha. To produce 1 kg of marketable yield with seepage and drip irrigation, broccoli used 1,999 l of water and 684 l, sweet corn 916 l and 193 l, and zucchini 249 l and 59 l, respectively.*

VEGETABLE PRODUCTION in southwest (SW) Florida is based upon the use of full bed plastic mulch, large amounts of high analysis fertilizers and irrigation water (Geraldson 1962, 1970). This high energy input farming method assures the growers a relatively "safe" production of good quality and a high yield per unit area, provided weather conditions are favorable and there is no serious infestation of the crop by plant pests. Recently, there is increased pressure on the agricultural industry to reduce the amount of water used in the production of various crops to prevent excessive depletion of underground water, which is used as the major source of irrigation water. There is also a trend to reduce the contamination of streams and lakes by plant nutrients in the surface or subsurface runoff water from the highly fertilized fields.

To reduce the water consumption by the agricultural industry, drip or trickle irrigation, instead of the traditional seepage irrigation, has been tried by researchers and growers. Bryan et al. (1975) compared the amount of water from sprinkler and drip irrigation needed to produce sweet corn on calcareous soils. Only 152 mm of water/m² in the dry season was applied with the drip system to grow the crop.

Csizinszky and Overman (1978a) raised a fall crop of broccoli with 312 mm/m² of drip irrigation water from a single micropore tube per bed. The field also received 114 mm of rain during the 64-da growing season for a total of 426 mm of water. Because the efficiency of the seepage and drip irrigation systems for the production of vegetable crops under SW Florida conditions have not been compared; therefore, investigations were started at the AREC-Bradenton to compare these 2 irrigation systems on vegetable

¹Florida Agricultural Experiment Stations Journal Series No. 1789.

crops. Results of the experiments conducted in the spring season of 1978 are reported herein.

MATERIALS AND METHODS—In February 1978 seedlings of broccoli (*Brassica oleracea* var. *Italica* Group (L.) cv. 'Green Comet Hybrid') and zucchini squash (*Cucurbita pepo* (L.) cv. 'Fordhook') were transplanted and seeds of sweet corn, (*Zea mays* (L.) cv. 'Silver Queen') were sown in a field of Myakka fine sand with a spodic horizon at 94 cm depth. Beds were formed with 1.37 m centers, 20 cm high, and 76 cm across the top. In the seepage irrigated land, lateral ditches were formed after every 7th row, thus a total of 5,605 row m/ha could be used for production. In the drip irrigated land 7,299 row m/ha were used. Because of this difference in usable land, nutrients applied are expressed as kg per 100 row m, rather than on a per ha basis. For both irrigation systems 2.77 kg N, 1.07 kg P, 3.84 kg K, and 0.3 kg Mg/100 row m in the form of 18-0-25 + 2 Mg fertilizer and 20% superphosphate containing fritted micronutrients were applied. Superphosphate was broadcast on the surface and the 18-0-25 + 2 Mg was applied in 2 bands, 30 cm from the bed center in the seepage and 20 cm from the center in the drip irrigated field. In the drip irrigated field, micropore tape (duPont Viaflo, type 2^(R)W, single seam) was placed 5 cm from the center and 5 cm below the soil surface. Black polyethylene film, 1.25 mil thickness, was laid over the entire bed in both treatments. Water flow in the seepage irrigated land was at a rate of 13.31 l/m²/day throughout the season and irrigation started 2 da before planting. In the drip irrigated land the flow rate was 2.27 l/min/tube for a 70 m long row, at 0.246 kg/cm² pressure, regulated by a Dole flow control valve (Eaton Corp., Carol Stream, IL). Water delivery time was adjusted each 10 da interval to provide adequate moisture as plant size, temperature, daylength, and daily evaporation changed (Marlowe and Rogers, 1976). Open pan evaporation and air temperatures were measured daily at the AREC-Bradenton (Fig. 1). Irrigation was discontinued in both fields when daily precipitation exceeded 19 mm. Irrigation schedules are in Tables 1 and 2. Rows were divided into 7.6 m long plots and crops were planted in a completely randomized block design. Seepage irrigated plots were replicated 4 times and drip irrigated plots 3 times. Within row plant spacings were 46 cm for broccoli and 76 cm for zucchini, sweet corn was seeded 20 cm apart in double rows (10 plants/row m). Plants were sprayed weekly with approved pesticides. At harvest, number and weight of marketable yield were taken. Statistical analysis was not performed on the data because on the spodosols field experiments with drip and seepage irrigation systems can not be set up and randomized on the same piece of land. The high soil water table maintained with the seepage system makes impossible the separation and evaluation of the 2 irrigation systems on the same land.

RESULTS AND DISCUSSION—Irrigation schedules, amount of water applied per day and for the 10-da periods throughout the season for the seepage and drip systems are in Tables 1 and 2. The application rate of water in the

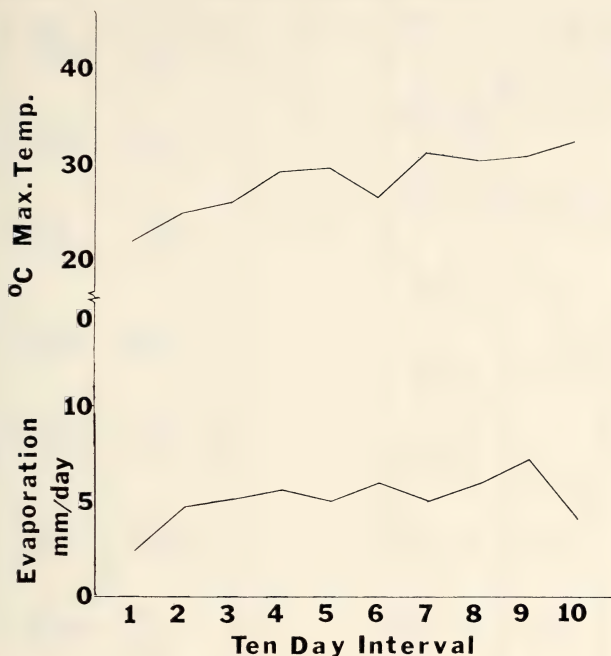


FIG. 1. Cumulative values of pan evaporation and maximum temperatures during the Spring 1978 growing season at AREC, Bradenton.

seepage system was uniform throughout the season, affected only by the number of rainy days during which irrigation was turned off. Thus, the water supply to each plant per day was also constant, depending on the plant density per ha for the 3 crops. Broccoli received 10.87, sweet corn 2.38, and zucchini 18.04 l/plant/da throughout the season (Table 3). In the drip system, the amount of water received by the 3 vegetable crops/plant/day varied as the season progressed, because the water flow time was regulated for each 10-da period (Table 3).

The amount of water applied by irrigation for the crops in the seepage method was much higher than that in the drip system (Table 4). Broccoli received 3.5, sweet corn 2.8, and zucchini 3.1 times more water with seepage than with drip irrigation. With seep irrigation a near constant water table is maintained on Myakka fine sandy soils with a spodic horizon. From the water table an almost uniform moisture is supplied for the plants with minimum water stress (Geraldson, 1970). In the drip irrigation system the

TABLE 1. Seep irrigation schedule for vegetables.

	Period									
	Feb 23- Mar 4	Mar 5- 14	Mar 15- 24	Mar 25- Apr 3	Apr 4- 13	Apr 14- 23	Apr 24- May 3	May 4- 13	May 14- 23	May 24- Jun 1
Number of irrigation days	8	8	10	10	10	10	10	6	6	9
liters/m ² /day	13.31	13.31	13.31	13.31	13.31	13.31	13.31	13.31	13.31	13.31
m ³ /ha day	133	133	133	133	133	133	133	133	133	133
m ³ /ha for period	1,064	1,064	1,330	1,330	1,330	1,330	1,330	798	798	1,197
Rainfall, mm	29	50	0	0	3	1	1	94	126	18

TABLE 2. Drip irrigation schedule for broccoli, sweet corn and zucchini.

	Period									
	Feb 27 Mar 10	Mar 11- 20	Mar 21- 30	Mar 31- Apr 9	Apr 10- 19	Apr 20- 29	Apr 30- May 9	May 10- 19	May 20- 29	
Number of irrigation days	10	10	10	10	10	10	7	8	7	
liters/m ² /day	0.555	0.854	3.191	6.682	7.126	6.976	6.383	6.383	3.896	
m ³ /ha/day +	5.55	8.54	31.91	66.82	71.16	69.76	63.83	63.83	38.96	
m ³ /ha for period	56	85	319	668	713	698	447	511	273	
Rainfall, mm	78	-	-	-	3	2	94	92	52	

1 m³ = 0.00938 acre inch of water.

soil water table and soil moisture content under the plastic mulch varies with the rainfall (Csizinszky and Overman, 1978b). In their experiments, increasing the amount of water by using 2 tubes per plant bed, thereby doubling the rate of irrigation, increased the horizontal movement of the water to a very small degree. Except after heavy rainfall, the shoulder regions of the bed with drip irrigation remained dry and the fertilizer placed in this region was not available for the plants. Therefore, different methods of fertilizer placement are required in the 2 irrigation systems due to the different water movement patterns under plastic mulch.

Yield of broccoli, per plant and per ha, was higher with seepage irrigation (Table 5). The size of broccoli sprouts in the drip irrigated plots was small, only 64% of the size of the sprouts grown with seepage irrigation. Sweet corn in the drip irrigated plots did not germinate uniformly. Plant stand was only 88% compared to seepage irrigated plots. There were no differences in yield per plant between the 2 irrigation systems and per ha yield was higher with drip irrigation. Zucchini had a higher per ha yield with drip irrigation. The higher per ha yield with drip irrigation, even if the per plant yields are equal or somewhat below compared to per plant yields from seepage irrigated plots, is due to the 24% higher number of plants per ha with the drip system (Table 5). In the 7 row seepage irrigation system used at the AREC-Bradenton, 24% of the land is taken up by the lateral ditches which distribute the irrigation water in the length of the field. These ditches also serve as drainage ditches after a heavy rainfall. Under the conditions in SW Florida some type of drainage system will be required in the drip irrigated fields to facilitate the rapid runoff of water during or after a rainy period.

Water used per kg of marketable yield declined as yield of the vegetable crops increased (Table 6). Broccoli used the highest amount of water per kg of yield, followed by sweet corn and zucchini. If water supply becomes critical in the future we may have to select the vegetable crop on the basis of nutritional value produced per hectare and the amount of water required by the crop to produce 1 kg of marketable yield. Other points to be considered when selecting an irrigation system for crop production are the larger number of plants which have to be raised per unit area and the higher cost of installation of the drip system. The number of drainage ditches necessary in drip irrigated fields to facilitate the rapid runoff of water during or after a rainy period may need further research. Soil moisture content with drip irrigation is different than that of seepage irrigated land. In a seepage irrigated field, soil water from the constant water table moves by capillary to the soil surface between the beds and in the beds under the plastic mulch. In a drip irrigated field, soil between the plant beds is dry and the soil water table is low (Csizinszky and Overman, 1978b). Therefore, much of the rain is absorbed by the soil and the water is free to percolate vertically; thus, there is less likelihood of water stagnation in these fields.

In the experiments no attempt was made to regulate the flow of water in

TABLE 5. Yield of broccoli, sweet corn and zucchini with seep and drip irrigation systems.

	Crop					
	Broccoli		Sweet corn		Zucchini	
	Seep	Drip	Seep	Drip	Seep	Drip
Number of plants/ha	12,235	15,930	55,940	64,214 ¹	7,375	9,600
Yield per plant, kg ²	0.307	0.198	0.191	0.189	6.13	6.32
Yield per ha, tons ²	3.76	3.15	10.68	12.14	45.21	60.67

¹88% of seeds germinated.²Average of 4 replications for seep and 3 replications for drip irrigated plots.

TABLE 6. Water applied per plant with seep and drip irrigation to produce 1 kg of marketable yield.

	Crop					
	Broccoli		Sweet corn		Zucchini	
	Seep	Drip	Seep	Drip	Seep	Drip
Irrigation water, liters/plant	614	135	175	55	1,524	374
Rain, liter/plant	68	52	54	47	434	333
Total water, liter/plant	682	187	229	102	1,958	707
Irrigation water, liter/kg of yield	1,999	684	916	293	249	59
Total water, liter/kg of yield	2,220	948	1,200	542	319	112

the seepage irrigated plots. Large amounts of the water ran off at the end of the lateral ditches. At the AREC-Bradenton, experiments are underway to regulate the amount of water applied by seepage irrigation in the production of vegetable crops, without reducing the quantity and the quality of their yield. In summary, with the drip irrigation system in SW Florida different drainage arrangements, fertilizer placements, and irrigation schedules have to be used in the fields than with the existing seepage irrigation system. The amount of water saved in the vegetable production with drip irrigation has to be considered against the higher equipment and installation costs and the lower quality and yield of certain vegetable crops.

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Florida Sci. 43(4):285-292. 1980.

OCCURRENCE OF THE BALANOMORPH BARNACLE *XENOBALANUS GLOBICIPITIS* STEENSTRUP, 1851 (CORONULIDAE) ON THE ATLANTIC BOTTLENOSED DOLPHIN *TURSIOPS TRUNCATUS* IN THE GULF OF MEXICO—Henry R. Spivey, Department of Biological Science, Florida State University, Tallahassee, Florida 32306.

ABSTRACT: The monotypic cirriped genus *Xenobalanus* is reported from the Gulf of Mexico for the first time.

THE pseudopedunculate sessile barnacle *Xenobalanus globicipitis* is a widely distributed species found exclusively on fins and flukes of Cetacea from latitude 71°N (Ingöy) to 62°S (South Shetland Islands). Worldwide it has been recorded from the following hosts: *Balaenoptera borealis*, *B. physalus*, *B. musculus*, *Orcinus orca*, *Pseudorca crassidens*, *Delphinus delphis*, *Grampus griseus*, *Tursiops catalania*, *Globicephala melaena*, *G. intermedius* (cf. Nilsson-Cantell, 1930), *G. macrorhynchus* (cf. Spivey, 1977),

Tursiops truncatus (cf. Dollfus, 1968), *Phocoena phocoena*, *Feresa attenuata* (cf. Stubbings, 1965), *Stenella styx* (cf. Pilleri, 1970), and *Neomeris phocoenoides* (cf. Devaraj and Bennet, 1974).

Two specimens of this whale barnacle were found attached to the fluke of a dead Atlantic bottlenosed dolphin washed ashore at Alligator Point, Franklin County, Florida (29°54'N, 84°26'W), 15 February 1979. Dorsal body of the dolphin, *Tursiops truncatus* (Montagu), displayed several large unhealed puncture wounds according to Mr. Douglas C. Gleeson who examined the find.

Although *X. globicipitis* is best known from North Atlantic localities, it has not been reported previously from the Gulf of Mexico. It is a common species on the short-finned pilot whale (*Globicephala macrorhynchus*) seen in adjacent waters along the northeastern Florida coast. Described but not named, the barnacle has also been noted in this Atlantic locality on *T. truncatus* (vide Caldwell and Caldwell, 1972). Previous records from the Atlantic bottlenosed dolphin are from the western Mediterranean (Dollfus, 1968; Pilleri, 1970).

That specimens of *X. globicipitis* attached to *T. truncatus* may have entered the Gulf of Mexico from the Atlantic or Caribbean is unlikely. Bottlenosed dolphins usually do not migrate over such long distances (Caldwell and Caldwell, 1972), and present specimens of *X. globicipitis*, measuring 16 and 22 mm in height, are young in age.

ACKNOWLEDGMENTS—I thank D. C. Gleeson of Gulf Specimen Company, Panacea, Florida for informing me of this find and for donation of material.

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Florida Sci. 43(4):292-293. 1980.

STUDIES OF THE FLORIDA
CONVOLVULACEAE — III. CUSCUTA

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ABSTRACT: *Field and herbarium studies of the parasitic plants of the genus CUSCUTA have been made in Florida. Keys, taxonomy and illustrations are given for 9 species.*

CUSCUTA is a genus of 140-150 species of worldwide distribution. Subgeneric classification has been proposed by Yuncker (1921, 1932, 1965) whose studies form the basis for all modern examination of the group. Several species have been spread around the world as contaminants in seed of cultivated plants, and probably by other means. Arguments have been proposed to separate these parasitic members from the Convolvulaceae into a separate family, the Cuscutaceae (e.g., Small, 1933). The major basis for such separation is the parasitic habit, which has been considered insufficient (Austin, 1973, 1975, 1979). Linnaeus apparently based the generic name on the Arabic "kushkut" which may be roughly translated as "a tangled wisp of hair."

Florida distribution is based on specimens deposited at the Fairchild Tropical Garden, Florida Atlantic University, Florida State University, Missouri Botanical Garden, Smithsonian Institution and the University of South Florida.

Most herbaria handle these plants as if they were "normal" specimens. Indeed, such treatment results in material that quickly becomes broken and valuable parts become lost. Suggestions on how to handle these parasitic plants were offered recently (Austin, 1979).

Cuscuta L., Sp. Pl. 124. 1753; Gen. Pl. ed. 5, 60. 1754. Type: *Cuscuta europaea* L.

Vines without chlorophyll; the stems twining, filiform, yellow or orange or rarely greenish, attached to host plants by haustoria; roots withering and absent from mature plants. Leaves reduced to minute scales. Inflorescences cymose, composed of small whitish flowers: calyx gamosepalous, 5-lobed, the sepals rarely almost free; corollas urceolate, tubular or more often campanulate, the 5 lobes various, usually with basal scale-like appendages inside opposite the stamens, forming a corona; the pollen 3-colpate; ovary 2-locular; locules 2-ovulate; stigmas 2, distinct or rarely united, terminal, the stigmas capitate to linear. Fruits capsular or circumscissile near the base; seeds (1-3-)4, smooth to roughened.

KEY TO FLOWERING SPECIMENS

- a. Flowers tubular.
 - b. Inflorescences bracteate, compact, the calyx polysepalous 3. *C. compacta*
 - b. Inflorescences not bracteate or congested, the calyx gamosepalous.
 - c. Styles 2, exerted from corollas. 1. *C. americana*
 - c. Styles 1, included within corollas. 4. *C. exaltata*
- a. Flowers campanulate.
 - d. Corollas tube longer than calyx.
 - e. Calyx lobes acute; corolla lobes inflexed. 7. *C. indecora*
 - e. Calyx lobes obtuse; corolla lobes erect or reflexed.
 - f. Calyx almost enclosing corolla tube; flowers 2 mm long, the petals usually glandular only along the central part of the lobe. 5. *C. obtusiflora*
 - f. Calyx shorter than the corolla tube; flowers 2-4 mm long, the petals glandular or not. 6. *C. gronovii*
 - d. Corolla tube shorter or equal to calyx.
 - g. Calyx lobes triangular, acute; flowers 2-3 mm long. 9. *C. umbellata*
 - g. Calyx lobes broadly ovate, obtuse to broadly acute; flowers 1.5-3 mm long.
 - h. Calyx angled at sinuses; flowers 1.5-2 mm long. 8. *C. pentagona*
 - h. Calyx rounded at sinuses; flowers 2-3 mm long. 2. *C. campestris*

KEY TO FRUITING SPECIMENS

- a. Styles united. 4. *C. exaltata*
- a. Styles distinct.
 - b. Capsules opening to circumscission.
 - c. Calyx lobes obtuse; corolla longer than broad. 1. *C. americana*
 - c. Calyx lobes acute; corollas about as long as broad. 9. *C. umbellata*
 - b. Capsules not opening by circumscission.
 - d. Capsules ovoid, conic or beaked, commonly longer than broad. 6. *C. gronovii*
 - d. Capsules globose or depressed-globose.
 - e. Calyx polysepalous; inflorescences bracteate, compact. 3. *C. compacta*
 - e. Calyx gamosepalous; inflorescences not bracteate or congested.
 - f. Capsules with a definite thickened stylopodium; flowers $\pm$ thick and fleshy, papillate. 7. *C. indecora*
 - f. Capsules not especially thickened at the top; flowers thin and smooth.
 - g. Corolla lobes obtuse. 5. *C. obtusiflora*
 - g. Corolla lobes acute.
 - h. Calyx lobes overlapping at the sinuses to form angles; flowers 1.5-2 mm long. 8. *C. pentagona*
 - h. Calyx lobes not overlapping to form angles at the sinuses; flowers mostly 2-3 mm long. 2. *C. campestris*

1. *Cuscuta americana* L., Sp. Pl. 124. 1753. Type: specimen in herb. Linnaeus (LINN, not seen; microfiche). Fig. 1A.

Nemepis americana (L.) Raf., Fl. Tellur. 4:91. 1836.

Cuscuta graveolens H.B.K., Nov. Gen. Sp. Pl. 3:122. 1819. Type:

Venezuela. Sucre. Cumaná. A. Bonpland (microfiche).

Stems mostly 0.4-0.6 mm in dia. Flowers subsessile and closely compacted into many-flowered clusters; calyx tubular, synsepalous, about equal in length to the corolla tube, the lobes broadly ovate, overlapping, obtuse, usually shorter than broad; corollas 2-3 mm long, cylindrical, included in the calyx, usually only the short, ovate, obtuse, upright to slightly spreading lobes exerted; scales triangular, rarely oblong, fringed with short processes,

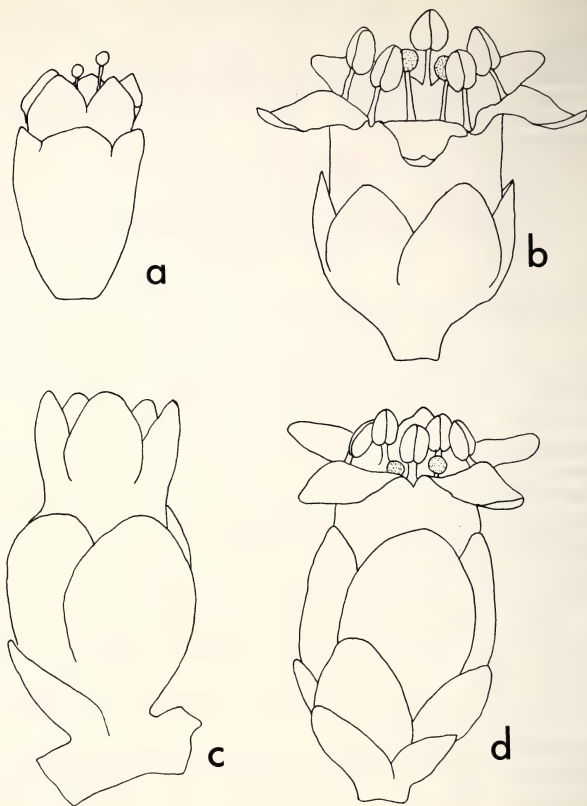


Fig. 1. Large-flowered species of *Cuscuta*. A. *C. americana*. B. *C. gronovii*. C. *C. exaltata*. D. *C. compacta*.

shorter than tube or sometimes reaching the stamen base; stamens subsessile, included, the anthers oval and frequently with the connective apiculate; styles longer than the globose ovary, reaching the corolla lobes or slightly exserted, stigmas capitate. Fruits capsular and circumscissile, globose-ovoid, capped by the withered corolla; seeds 1.5 mm long, usually 1, hilum small, oval, oblique or reduced to a round spot.

Common plants in the West Indies, less common in Mexico and rare in the U.S.A. In South America known from Surinam, Brazil, Colombia, Argentina and Venezuela. Found on many hosts, mostly woody. Flowering from September to December and April to May.

Although Yuncker (1921) did not include this species in Florida, he did later (1932, 1965) and there are specimens collected in Miami in the 1930's and 1940's. The species has not been seen in the State recently.

2. *Cuscuta campestris* Yuncker, Mem. Torrey Bot. Club 18:138. 1932. Type: U.S.A. Texas. Lindheimer 126 (holotype MO).

C. pentagona var. *calycina* Engelm., Amer. Jour. Sci. Arts 45:76. 1845. Type: based on the same specimen as *C. campestris*.

C. arvensis sensu Engelm. in Gray, Man. Bot. ed. 2. 336. 1856, in part. *C. pentagona* auctt. non Engelm. (1842).

Stems 0.35-0.4 mm in dia. Flowers 2-3 mm long, appearing larger in fruit, smooth or with scattered pellucid, gland-like cells, pedicels mostly shorter than the flowers, in glomerate-cymose clusters; calyx lobes about as long as the corolla tube, overlapping at the very base, but not markedly angular at the sinuses, ovate to oval-ovate, about as long as wide, obtuse; corolla lobes triangular to sublanceolate, about as long as the tube, spreading to reflexed, often granulate, the acute tips inflexed; scales reaching the filaments, ovate-oblong, abundantly fringed; style slender to slightly subulate, as long as or longer than the ovary. Fruits capsular, depressed-globose, the withered corolla remaining around the lower half.

Native of the U.S.A. but apparently widespread around the world because it parasitizes clover and alfalfa. Flowering from June to July.

Lakela and Craighead (1965) and Long and Lakela (1971) reported this species from southern Florida. Most of the specimens which presumably formed the basis of these reports were *C. pentagona*, although there were 2 other species misdetermined. Apparently this species was not collected in the State until 1976, when it was found in Leon County.

3. *Cuscuta compacta* Jussieu in Choisy, Mem. Soc. Phys. Genève 9:281. pl. 4. f. 2. 1841. Type: Hab. Amer. septentrionalem. Beauvois (presumably G-DC, not seen; paratype by Gray GH). Fig. 1D.

C. compacta var. *efimbriata* Yuncker, Ill. Biol. Monogr. 6:167. f. 54f. 1921. Type: Florida. Duval Co. Fredholm 305 (holotype US).

Stems 0.6 mm. or more in dia. Flowers sessile, in compact clusters or scattered glomerules; calyx of distinct sepals, cupped, orbicular or oval, shorter than the corolla tube, surrounded by 3-5 similar, appressed bracts; corollas 4-5 mm long, cylindrical, excluded from the calyx, becoming urceolate in fruit, the lobes spreading and reflexed, oblong, obtuse; scales with long processes, about reaching the stamens; stamens shorter than the corolla lobes, exerted, the anthers oval; styles about as long or shorter than the globose ovary, reaching to the corolla lobe sinuses, stigmas capitate. Fruits capsular, globose-conic, slightly pointed, capped by the withered corolla; seeds 2.6 mm long, globose, ovate to angled or flattened, scurfy, hilum oblong, oblique.

Found on a large assortment of woody and herbaceous hosts from the northeastern U.S.A. south to Florida and west to Texas and Arkansas. Flowering from July, September and December.

While mostly found in northern and central Florida, there are some recent collections from Collier County. These plants are unusual in the State in having bracts which surround the base of the flowers.

4. *Cuscuta exaltata* Engelm., Trans. Acad. Sci. St. Louis 1:513. 1859. Type: U.S.A. Texas, New Braunfels. Lindheimer 472 (holotype MO). Fig. 1C.

Stems 1-2 mm in dia. Flowers sessile or subsessile, in spicate panicles; calyx synsepalous, the fleshy, thick, concave, ovate-orbicular, obtuse, overlapping lobes nearly as long as or equalling the corolla tube; corollas 4-5 mm long, cylindrical, at least the lobes exserted, these obtuse, ovate-orbicular, overlapping; scales of 2 dentate or emarginate wings on either side of the filament attachment, toothed above; stamens shorter than corolla lobes, sessile at the throat, included, anthers oval; styles as long as the globose ovary, partially or completely united, but easily separated, stigmas flat. Fruits capsular, circumscissile, ovate-globose, capped by the withered corolla; seeds 3-3.5 mm long, rostrate and trigonous, hilum oblong, oblique and transverse.

Although the plants are fairly common in Texas, apparently only 3 collections have been made in Florida. Yuncker (1932) cited a Baker collection from Volusia County collected in 1908 that I have not seen. Two recent collections have been made, 1 in Pinellas County in 1976 (M.L. Ward FSU) and 1 in Lake County in 1979 (Daubenmire USF). The single style and scales without fringed processes are unique traits among Florida plants. This species is parasitic on several woody hosts. Flowering in September and November.

5. *Cuscuta obtusiflora* H.B.K. var. *glandulosa* Engelm., Trans. Acad. Sci. St. Louis 1:492. 1859. Type: U.S.A. Georgia. Boykin (holotype MO). Fig. 2D.

C. glandulosa (Engelm.) Small, Fl. S.E. United States 969. 1903.

Stems 0.4-0.6 mm in dia. Flowers 2 mm long, subsessile, in compact, glomerulate clusters; calyx synsepalous, almost enclosing the corolla tube, lobes unequal, rounded-ovate, obtuse, irregularly serrulate, not overlapping; corollas may be glandular, at least in central strip of lobes, these triangular- to broadly-ovate, obtuse, spreading to reflexed; scales large, ovate, prominently fringed, mostly exserted; stamens shorter than the lobes, filaments about equalling or longer than the oval or cordate anthers; styles shorter than or equalling the 2-globose ovary, stigmas capitate. Fruits capsular, depressed-globose, not circumscissile, styles becoming subulate and divergent from the large intrastylar aperture; seeds 1.5 mm long, ovate, hilum oblong, diagonal.

The tautonymic variety is found in South America; the var. *glandulosa* is found in the southern U.S.A. from California to Georgia and Florida, the Greater Antilles and northern Mexico. This species grows on a number of hosts but often on *Polygonum*. Flowering from September to December.

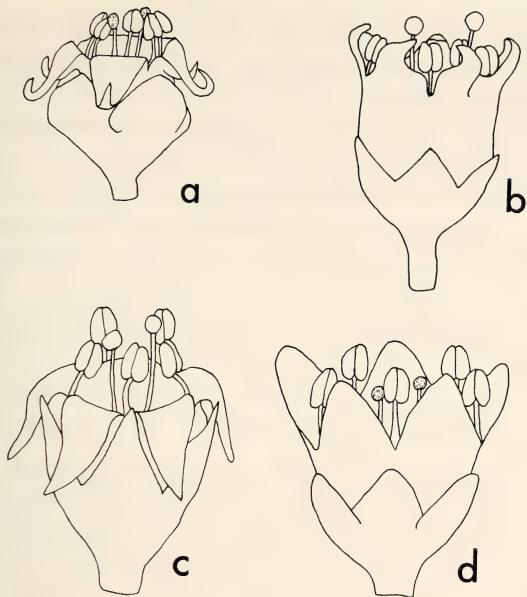


Fig. 2. Medium- and small-flowered species of *Cuscuta*. A. *C. pentagona*. B. *C. indecora*. C. *C. umbellata*. D. *C. obtusiflora* var. *glandulosa*.

This species is related to *C. gronovii*; in fact, Yuncker put them in the same subsection. Fruits are normally depressed-globose and lack a beak in var. *glandulosa*; they are mostly obpyriform and beaked in *C. gronovii*.

6. *Cuscuta gronovii* Willd. in Roem. & Sch., Syst. Veg. 6:205. 1820. Type: U.S.A. Virginia. (not found). Fig. 1B.

C. gronovii var. *vulgivaga* Engelm., Trans. Acad. Sci. St. Louis 1: 508. 1859. Type: U.S.A. western New York. Gray (not seen).

Stems 0.4-0.6 mm or more in dia. Flowers 2-4 mm long, on pedicels shorter than or about equalling the flowers, in loose or densely paniced cymes; calyx lobes broad, ovate, orbicular or oblong, obtuse, overlapping, shorter than corolla tube; corollas narrowly campanulate, almost tubular, the lobes mostly shorter than the tube, ovate, obtuse, spreading; scales mostly equalling the tube, usually oblong, fringed; stamens about as long as the lobes, filaments longer than the oval anthers; styles mostly shorter than the globose-conic ovary. Fruits capsular, globose-conic to obpyriform, beaked, occasionally glandular, enveloped at base by withered corolla; seeds 1.5 mm long, 2-4 per fruit, ovate, rosulate, hilum linear, oblique to transverse.

Having no apparent specialization for hosts, this species is found on many different woody and herbaceous hosts. Mostly found in the U.S.A., but also known from the West Indies; introduced into Europe. Flowering in July, September to December.

Two old collections are known from Lee County (Hitchcock 232, Simpson 380); all recent specimens are from the Panhandle.

Flowers and fruits may be glandular or not; if they are, they may be confused with *C. indecora*. The lobes are inflexed at the tips in *C. indecora* and reflexed in *C. gronovii*. Unless specimens are in fruit it is hardly possible to separate this species from *C. obtusiflora* var. *glandulosa*. Corolla shapes differ slightly, being more nearly tubular in *C. gronovii*.

7. *Cuscuta indecora* Choisy, Mem. Soc. Phys. Genève 9:278. pl. 3. f. 3. 1841. Type: Mexico. ad Metamoros. Berlandier 2285 (holotype G-DC, not seen). Fig. 2B.

C. indecora var. *neuropetala* (Engelmann) Hitchcock, Contrib. U.S. Nat. Herb. 3:549. 1896. Type: U.S.A. Texas. In wet prairies near Houston. Lindheimer 124 (holotype MO).

Stems 0.4-0.6 mm in dia. Flowers 2-2.5 mm long, white, fleshy, papillate, on pedicels longer than the flowers; calyx lobes triangular-ovate, acute to somewhat obtuse, shorter than the corolla lobes; corollas campanulate, the lobes erect to spreading, triangular, acute, with inflexed tips; scales as long as or longer than the corolla tube, ovate or somewhat spatulate, deeply fringed; stamens shorter than the lobes, anthers broad, oval, about equal to the filaments; styles as long as or slightly longer than the globose, pointed ovary, becoming divaricate in fruit. Fruits capsular, circumscissile, thickened at top and enlarged by the withered corolla; seeds 2-4, about 1.7 mm long, rounded or broader than long, scurfy, hilum small, oval, transverse or somewhat oblique.

This species is widely spread throughout the New World; reported from the U.S.A. to Argentina. Flowering from January, June, July and September.

These plants are easily confused with *C. pentagona* and *C. obtusiflora* var. *glandulosa*. Examination with a dissecting microscope will reveal the papillate nature of the petals in *C. indecora*, a trait absent from the other Florida species. In tropical American material the tube of the corolla is characteristically longer than the limb; they are often about equal in length in Florida plants.

8. *Cuscuta pentagona* Engelmann, Amer. Jour. Sci. Arts 43:349. pl. 6. f. 22-24. 1842. Type: U.S.A. Virginia. Norfolk. Rugel (holotype MO). Fig. 2A.

C. pentagona var. *typica* Yuncker, Ill. Biol. Monogr. 6:140. f. 33a-e, 112, 127. 1921, nom. illegit.

Stems 0.35-0.4 mm or rarely larger in dia. Flowers 1.5-2 mm long, inconspicuously glandular, on pedicels about equalling flowers in length, in

loose, cymose clusters; calyx mostly enclosing the corolla tube, loose, lobes mostly broader than long, broadly ovate, obtuse, broadly overlapping at sinuses, this gives the calyx an angled appearance; corollas with narrow, lanceolate, spreading lobes, the acute tips inflexed, about equalling the campanulate tube; stamens shorter than the lobes, filaments slender, longer than or equalling the oval anthers; styles about equalling or shorter than the globose ovary, stigmas small, globose. Fruits capsular, globose or depressed-globose, protruding from the withered corolla; seeds 1 mm long, globose, hilum short, oblong, terminal, transverse.

These vines are parasitic on a variety of herbaceous hosts such as *Lespedeza*, *Euphorbia*, *Aster*, *Ambrosia* and *Solidago*. The species is most abundant in the eastern United States, but also found west to California. Flowering in September, November, January, March and July.

9. *Cuscuta umbellata* H.B.K., Nov. Gen. Sp. Pl. 3:121. 1818. Type: Colombia. Inter Queretaro et Salamanca. A. Bonpland (fragment MO). Fig. 2C.

C. umbellata var. *typica* Yuncker, Ill. Biol. Monogr. 6:132. f. 9a-c, 115, 149. 1921, nom. illegit.

Stems 0.3-0.4 mm in dia. Flowers smooth or rarely slightly puberulent, 2-3 mm long, on pedicels longer or shorter than flowers, in dense, compound cymes, the ultimate umbellate divisions of 3-7 flowers; calyx turbinate, as long as or longer than the campanulate corolla, the lobes triangular-ovate, acute to acuminate; corolla lobes as long as or longer than the tube, reflexed, lanceolate, acute or acuminate; scales somewhat obovate or spatulate, moderately fringed, reaching the filaments or slightly exserted; stamens shorter than the lobes, anthers oblong to oval, shorter than or equalling the filaments; styles longer than the globose ovary. Fruits capsular, depressed-globose, with a ring of thickened knobs around the intrastylar aperture, tardily circumscissile, surrounded by the withered corolla; seeds 1 mm long, angled, oblique, oval, hilum oblong, linear, transverse.

Parasitic on a number of coastal plants including *Sesuvium*, *Boerhavia*, *Portulaca*, *Atriplex*, *Suaeda*, *Alternanthera* and *Euphorbia*; occasionally inland. Several varieties are reported from the southwestern U.S.A. through Mexico, Central America and South America into Brasil. Apparently most commonly found in xeric, saline habitats. Flowering from June to September and December.

Rare in Florida, having been collected in Lee, Sarasota and Flagler counties. Two older collections are known, but they have no location data on the labels.

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Florida Sci. 43(4):294-302. 1980.

EMBRYOGENY OF THE CTENIZID SPIDER MYRMEKIAPHILA FLUVIATILUS (HENTZ)—John R. Tripp, Department of Biology, Florida Southern College, Lakeland, Florida 33802

ABSTRACT: *Myrmekiaphila fluviatilis* oviposited in late July and early August. Contraction began 4-5 da after oviposition. At day 10, the primitive cumulus migrated from the primitive plate to the edge of the germ disc. Gastrulation conformed closely with that of other ctenizids. Appendages became visible by day 12, but there was no development of a postabdomen, a condition unusual for a ctenizid. Hatching, which occurred 20-21 da following oviposition, was sometimes delayed while the spiderlings continued to develop within the chorion. This delay is noteworthy considering past attempts at categorizing spiders on developmental stages at hatching.

OUR knowledge of mygalomorph embryogeny has increased considerably since Holm's (1954) study of the diplurid, *Ischnothele Karschi* Bos and Lenz. More recent studies include those on *Atypus* (Yoshikura, 1958), *Conothele* (Crome, 1964), *Ummidia* (Yoshikura, 1972), and *Antrodiaetus* (Tripp, 1972). I give additional data on mygalomorph development.

Gravid females of *Myrmekiaphila fluviatilis* (Hentz) were collected from northern Florida during May 1974. Specimens were maintained in test tubes in the laboratory at 26°C. Oviposition occurred during 22-26 July and 1-5 August. Eggs from 18 cocoons were immersed in paraffin oil, incubated at 26°C, and examined. Measurements were made with an ocular micrometer. The number of eggs deposited within a cocoon ranged from 72-125 (mean. 95.5), and the results are based on observations of approximately 1000 eggs.

RESULTS—Each egg was 1.25 mm in dia. Migrating energids reached the egg's periphery 2-3 da after oviposition, and newly-formed blastomeres continued to divide at the surface. Contraction began at 4-5 da when the blastomere dia varied from 0.07-0.15 mm. After 5 da, when contraction was mostly complete, blastomere dia varied from 0.05 to 0.07 mm.

At day 9, early gastrulation movements were discernable. Several blastomeres were clumped at various sites over the vegetal pole of the egg. A primitive plate was formed by the coalescing of those clumps. All blastomere

diameters were 0.02 mm. By day 10, the primitive cumulus had formed and had begun migrating toward the edge of the developing germ disc.

During day 11, the cumulus disappeared; segmentation was evident. Appendages were visible by day 12. As the appendages developed, abdominal segments were added, but there was no development of a post-abdomen. *Myrmekiaphila*, therefore, displayed the Entelogyne-type of abdominal development.

Hatching occurred 20-21 da after oviposition although some specimens continued to develop within the chorion and hatched at a later date. Early hatching spiderlings were "prelarvae", and later hatching individuals shed their embryonic cuticle within the chorion and were "larvae" according to Vachon's (1957) terminology.

DISCUSSION—Gastrulation in *Myrmekiaphila fluviatilis* conforms closely with that described for *Ummidia fragaria* (Yoshikura, 1972). This is not surprising as both are ctenizids. In *Antrodiaetus unicolor*, the primitive plate developed into a thickened primitive plug (Tripp, 1972), and the blastopore of the plug was more pronounced than that for *Myrmekiaphila*. The germ disc of *Myrmekiaphila* is well-developed. Although the cumulus diameter is similar in both spiders, the cumulus of *Antrodiaetus* is larger in proportion to its germ disc than that of *Myrmekiaphila*.

Gastrulation in *Myrmekiaphila* appears to be Type B (mygalomorph-type) (Seitz, 1966). *Ummidia* (Yoshikura, 1972) also apparently conforms to this type. *Antrodiaetus*, however, would be Type C (extreme-mygalomorph type) and, as stated earlier (Tripp, 1972), is very similar to that described for *Segestia* (Holm, 1940).

The development of a postabdomen has generally been considered to be a primitive characteristic. The most extreme Haplogyne-type of abdominal development occurs in *Heptathela* (Yoshikura, 1955), *Atypus* (Yoshikura, 1958), *Segestia* (Holm, 1940), and *Antrodiaetus* (Tripp, 1972). The abdominal development of *Myrmekiaphila*, however, corresponds more closely with that of *Ischnothele* (Holm, 1954). Both lack a well-developed postabdomen. However, the ctenizids *Ummidia* (Yoshikura, 1972) and *Conothele* (Crome, 1963) apparently have well-developed postabdomens. Interpretation of these differences is difficult at this time. Assigning an important phylogenetic indicator to the type of abdominal development may be questionable. Of the 2 basic types of abdominal development, the Haplogyne-type indicates a more primitive condition. But the existence of a Entelogyne-type in a "primitive" spider raises some doubts as to the validity of this interpretation.

The developmental events controlling these 2 types of abdominal development are unknown. Holm (1954) suggested that the relative amount of yolk present may dictate the pattern of abdominal development. We now have enough data to show that egg size alone does not dictate the type of abdominal development.

Antrodiaetus (Tripp, 1972), *Atypus* (personal observation), and *Conothele* (Crome, 1962) have small eggs with a dia of approximately 1 mm. Eggs of *Ummidia* (Yoshikura, 1972) are 1.0-1.2 mm. These genera possess well-developed postabdomens. *Myrmekeiaphila* embryos, similar to those of *Ummidia*, lack a well-developed postabdomen. *Heptathela* (Yoshikura, 1952), with relatively huge eggs at 1.4 mm, does possess a well-developed postabdomen. There does not appear to be a direct correlation between egg size and abdominal development.

The variability of the stage at hatching may be due to the submergence in paraffin oil. Even when the hatching was delayed, the spiderlings kept developing and eventually hatched at a later stage.

Knowing that this variability is possible, at least in the laboratory, investigators should be cautious in categorizing spiders on the basis of hatching time.

ACKNOWLEDGMENTS—I am indebted to 2 undergraduates, Mary Claire Maltese and Elizabeth Ward Hackbarth, for their assistance in this work. The study was made possible by a Cottrell College Science Grant from the Research Corporation of New York.

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Florida Scientist

QUARTERLY JOURNAL
of the
FLORIDA ACADEMY OF SCIENCES

VOLUME 43

Editors

WALTER K. TAYLOR

HENRY O. WHITTIER



Published by the

FLORIDA ACADEMY OF SCIENCES, INC.
Orlando, Florida
1980

The Florida Scientist continues the series formerly issued as the Quarterly Journal of the Florida Academy of Sciences. The Annual Program Issue is published independently of the journal and is issued as a separately paged Supplement.

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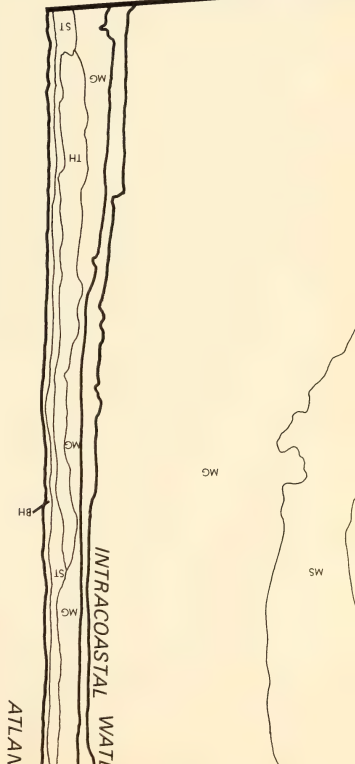
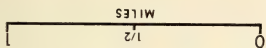
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FLORIDA SCIENTIST 42(4) was mailed on January 29, 1980.

FLORIDA SCIENTIST 43(1) was mailed on April 3, 1980.

FLORIDA SCIENTIST 43(2) was mailed on May 22, 1980.

FLORIDA SCIENTIST 43(3) was mailed on August 8, 1980.

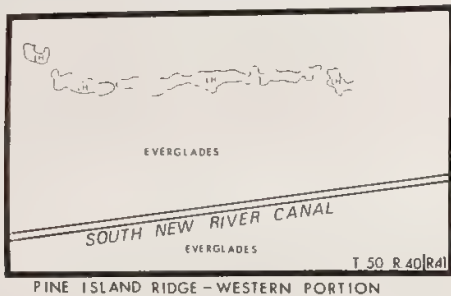


NORTH NEW RIVER CANAL

PINE ISLAND RIDGE

EVERGLADES

SOUTH NEW RIVER CANAL



BH - BEACH
ST - STRAND
TH - TROPICAL HAMMOCK
MG - MANGROVE
LH - LOW HAMMOCK
SP - SCRUB
DP - DRY PRAIRIE
WP - WET PRAIRIE
PF - PINE FLATWOODS
SW - SWAMP
MS - MARSH

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**VEGETATION MAP OF
COASTAL BROWARD
COUNTY**
Based on 1940 imagery,
Map 3

INTRACOASTAL WATERWAY

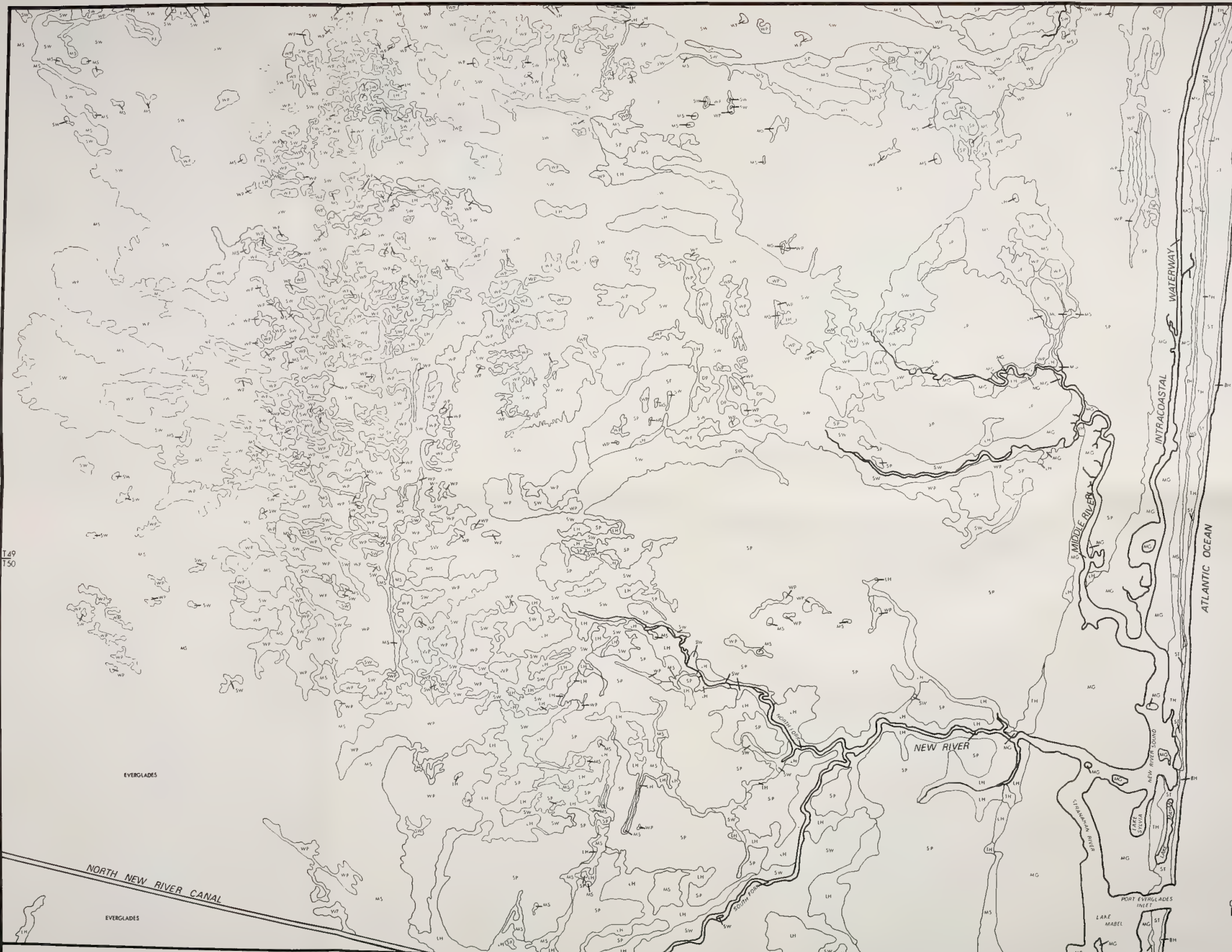
ATLANTIC OCEAN



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MILES

DADE COUNTY

R41/R42



- BH - BEACH
- ST - STRAND
- TH - TROPICAL HAMMOCK
- MG - MANGROVE
- LH - LOW HAMMOCK
- SP - SCRUB
- DP - DRY PRAIRIE
- WP - WET PRAIRIE
- PF - PINE FLATWOODS
- SW - SWAMP
- MS - MARSH

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Florida Atlantic University
1976

**VEGETATION MAP OF
COASTAL BROWARD
COUNTY**
Based on 1940 imagery,
Map 2

T49
T50

R41R42

R42R43

T.47
T.48

EVERGLADES

EVERGLADES

T.48
T.49

PALM BEACH COUNTY

HILLSBORO CANAL

PALM BEACH COUNTY

ATLANTIC OCEAN

BH - BEACH
ST - STRAND
TH - TROPICAL HAMMOCK
MG - MANGROVE
LH - LOW HAMMOCK
SP - SCRUB
DP - DRY PRAIRIE
WP - WET PRAIRIE
PF - PINE FLATWOODS
SW - SWAMP
MS - MARSH

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MILES

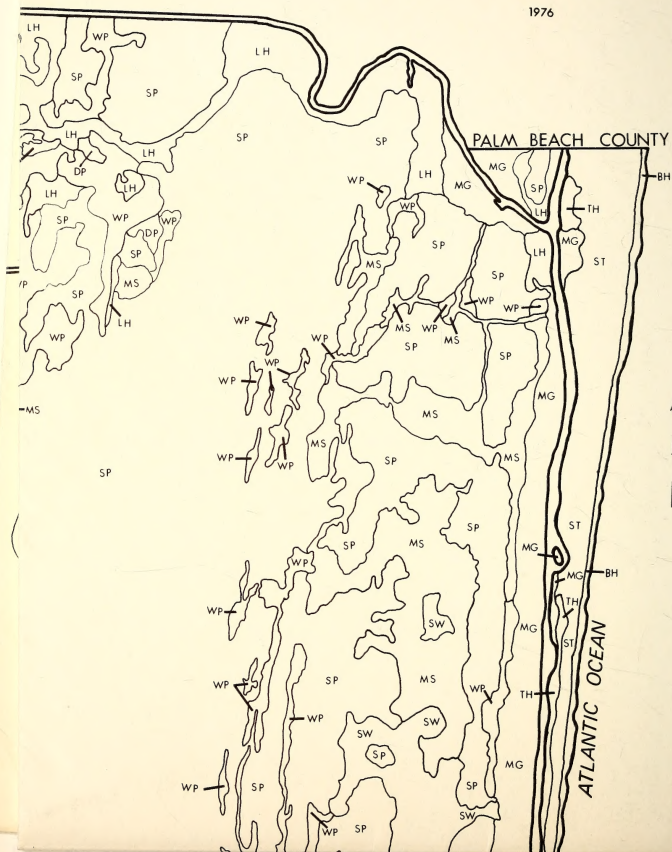
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